# Modelling the Societal Burden of Anthrax in Cattle in the Western Province of Zambia Using a Modification of Disability Adjusted Life Years

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## Abstract

**Background:** Anthrax, which is a naturally occurring zoonotic disease caused by the bacterium *Bacillus anthracis* has been endemic in Western Zambia. This paper estimated the societal burden of anthrax on cattle using Productivity Adjusted Life Years (PALYs) among cattle farmers in the Western Province of Zambia.

**Methods:** A quantitative cross-sectional study design was used to collect data from cattle farmers in Mongu, Nalolo and Limulunga districts of Western Zambia. The Disability-Adjusted Life Years (DALY) model for human populations was modified and adapted to the animal population model, PALYs, to estimate the societal burden of animal diseases. The integral calculator was used to estimate the societal disease burden of anthrax using PALY equations in three categories: PALYs without discounting and age weighting, PALYs with only discounting, and PALYs with discounting and age weighting.

**Results:** The results showed that anthrax affected the quality of life years lived by animals significantly due to years lost due to disability (YLD) and years lost due to premature death (YLL). A cow, bull and ox lost about 34%, 39% and 37% of productivity years of its life span due to anthrax. This shows that a bull lost most years of productivity seconded by an oxen and lastly, a cow. Anthrax further caused a total loss of 459,280.90 PALYs in the three districts. The quality of life is improved, and productivity losses are reduced to almost 0% for all three types of animals by introducing effective anthrax control measures in the absence of other adverse health conditions.

**Conclusion:** Anthrax negatively affected livestock production due to significant loss of healthy years of life and loss of quality of life. Since bulls lost most of the productivity years of their life span, we argue that transportation, draught power, sells as well as socio status were the most affected as these are usually performed by the bull, the most productive. Therefore, it is important to minimise the loss of cattle productivity through morbidity and mortality. Different intervention programmes for the same disease can be compared in cost-effective analysis using PALYs as one of the tools. Therefore, societal burden of diseases should also be applied on top of other existing methods used to assess the impact of diseases on animals to enable policymakers to have a complete and comprehensive picture of the impact.

**Keywords:** DALYs, PALYs, YLD, YLL, Anthrax, Cattle, Zambia

## Introduction

Cattle are generally important livestock as they provide humans with meat, milk, employment, drought power, and contribute to public revenue [7]. In Africa, cattle play many vital roles such as nutrition, income generation, assets, security, social and cultural functions, with their main products being meat, milk, hides, and manure and traction power [10]. In Zambia, cattle production has been targeted as a critical source of revenue and contributes about two-thirds to its Gross Domestic Product (GDP) [10]. The traditional cattle farmers account for 84% of the total cattle population, while commercial cattle farmers own 16% [9]. Cattle are kept for income, draught power for use in the cultivation of crops, source of transport in the form of ox-carts, sources of milk and meat, a symbol of status, manure for fertilising crop farms and use of payment of dowry during marriages [9]. Stakeholders such as farmers, food business owners, consumers, traders, veterinary services, healthcare systems and the wider society are negatively affected by cattle diseases like anthrax [12]. Therefore, there is a need to provide policymakers with ways of assessing the burden of cattle diseases such as anthrax to assist them in decision-making.

Anthrax is a naturally occurring zoonotic disease caused by the bacterium *Bacillus anthracis.* In Zambia, anthrax is endemic in Western, North-Western and Muchinga provinces, and outbreaks have occurred in animals such as hippo, buffalo and cattle [5][6][9]. The disease occurs throughout the year and impacts negatively on the economy of the livestock industry and public health in Zambia. The disease has direct and indirect costs, such as treatment costs and reduced productivity in cattle, respectively [15].

Studies done in other parts of the world as well as in Zambia have used different methods to assess the burden of different livestock diseases which include anthrax. Cost benefit analysis of foot and mouth disease control in Ethiopia was done by assessing annual cost of FMD based on production loses, export loses and control costs. These were the costs and benefits of three potential strategies namely; ring vaccination (reactive vaccination around outbreak area supported by animal movement vaccination, targeted vaccination (annual preventive vaccination in high risk areas plus ring vaccination in the rest of the country) and preventive mass vaccination (annual preventive vaccination of the whole national cattle population). These were compared with no official control programme [16]. Ottee and Chilonda looked at a broader overview of the issues involved in estimating the cost of animal diseases and the benefits of their control by looking at livestock productivity and effects of diseases and also the direct and indirect loses due to animal diseases [11]. The effects of livestock diseases and their control on growth and development processes were assessed taking the value chain approach which includes keepers, users and eaters of livestock [2]. In Zambia, Siamudaala studied the socio-economic impact of the anthrax disease by assessing the cost of control strategies of anthrax using cost-benefit analysis [13]. These studies, have mostly, estimated the financial and economic impact of the cost of anthrax control. While the financial and economic impact of anthrax control has been determined, there has been no attempt globally to estimate how losses of cattle and their associated products (milk. meat, draught power) impact rural communities. Therefore, this study addressed this gap which was not covered by these previous studies.

## Materials and Methods

### Study Sites and Design

A quantitative cross-sectional study design was used to collect data from cattle farmers in Mongu, Nalolo and Limulunga districts of Western Zambia and Mumbwa district of Central Zambia. Data were collected on anthrax infections in hippos in the Mfuwe district of Eastern Zambia and Chama districts of Muchinga provinces. This is because the endemicity of anthrax was not in cattle but hippos in these provinces. For PALYs, only data collected from Western Zambia was used. Western Province was chosen because of the endemicity of anthrax disease in the province [6][14]. The total cattle population in the Western Province is estimated at 450, 949 [4].

### Sample Size Calculation

A sample size of 385 was calculated using Epitools (http://epitools.ausvet.com.au/) [7] which gave us a precision of at least, 5% plus or minus at a confidence level of 95% with a maximum variability of P = 0.5 (50%) and was statistically sufficient for random sampling calculated from a target population of about 300,000 traditional cattle farmers in Zambia.

### Sampling Techniques

Farmers were interviewed from selected catchment areas of four veterinary camps in the three districts. The camps were purposively selected after advice from the District Veterinary Officers (DVO's) on which areas have recorded anthrax outbreaks in the recent past. The camps selected were Mongu Central in Mongu, Nanjucha in Nalolo, and Ushaa and Limulunga in Limulunga districts. A veterinary camp is the smallest administrative unit of livestock production manned by a veterinary assistant who reports to the DVO. It is managed by a veterinary assistant who reports to the District Veterinary Officer and holds a maximum number of about five thousand herds of cattle [4]. A simple random sampling technique was used to select the farmers to interview in each veterinary campsite.

## Data Collection Techniques

Data was collected from the traditional cattle farmers using a structured questionnaire in a face-to-face interview. Before collecting the data, the questionnaire was pre-tested in Matemena, one of the communities in the catchment area of Mongu Central veterinary camp. This was done to ensure the reliability, clarity and validity of the questionnaire. Data collected included the number of the cattle owned by the farmer, reasons for keeping cattle, health condition of cattle, the productivity of cattle, cattle morbidity and mortality, and the cost for controlling and treating anthrax. The questionnaire was prepared in English and translated into local languages during interviews. The local languages included Silozi in Western Province and Chinyanja in Eastern and Central provinces. Farmers were interviewed at places where they could be found, for example, households, abattoirs and local markets, depending on the time of the day.

## Data Management and Statistical Analysis

Data were directly entered into Statistical Package for Social Sciences (IBM SPSS version 26). This package was used to perform descriptive statistics. The integral calculator (https://www.integral-calculator.com/), which is Mathematical Calculus software, was then used to calculate the societal disease burden of anthrax. This was done by inserting the values of each parameter in the formulas for PALY equations.

## Calculation of PALYs

The calculation of the PALYs was done on the data collected from the three districts of Western Zambia, namely; Mongu, Nalolo and Limulunga, where anthrax was endemic in the cattle population. In the other areas, anthrax was endemic in hippos and other wild animals and not cattle. Since there is no recovery once an animal suffers from anthrax, the disease results in two possible outcomes: death or disability before death. Therefore, in this study, we used each of these two scenarios to calculate PALYs.

Disability Adjusted Life Years (DALYs) model for the human population was modified and reformulated into productivity adjusted life years (PALYs) for the cattle population. This modified PALYs model was used to assess the burden of anthrax disease on cattle production [12].

PALYs for a disease or health condition are calculated as the sum of the years of life lost due to premature mortality (*YLLs*) in the cattle population and the equivalent 'healthy' years lost due to disability (*YLD*) for incidence cases of the health conditions [12].

PALYs for Cattle = *YLLs* for cattle + *YLD* for cattle. (1)

The PALYs were calculated in the following three ways;

1. Without considering age weighting and discounting.
2. With considering discounting.

3. With considering age weighting and discounting.

**Years of Life Lost Due to Disability**

The number of years lost due to disability for each disease is assumed to be proportional to the average duration of the disease (*I*). The proportionality constant comprises the number of incident cases (*N*) and the severity of the disease (*D*).

$$YLDs = N \times I \times D \quad (2)$$

**Years of Life Lost Due to Premature Mortality**

Years of life lost due to premature mortality $YLLs = N \times L$ (3).

Where: *L* was the standard life expectancy at the age of death (in years), and *N* was the number of deaths. Life expectancy was the expected number of years of life remaining at a given age.

**Standard Life Expectancy**

Life expectanc is the expected number of years of life remaining at a given age for cattle. This study collected standard life expectancy (*L*) at birth or life span from the questionnaire data. Study findings indicated that life expectancy was 15, 12 and 13 years for the cow, bull, and ox. The expected life expectance at 3 years was calculated as the difference between the life span and age at 3 years. According to the data collected, 3 years was the median age of onset of anthrax disease. At this age, the life expectancy for cows, bulls and oxen were respectively, 12, 9 and 10.

**Disability Weight**

Some inability to perform everyday tasks in a usual way was defined as a disability. Disability weight was a measure that reflected the severity of a cattle disease on a scale of 0 to 1 (with 0 representing perfect health and 1 representing death). This study used disability weights of level 3 because of the severity and acute nature of anthrax disease, which significantly affected animal productivity like rapid cessation of milk yield [1]. The disability 0.34, 0.5 and 0.66, were the minimum, average and maximum of the disability weight interval of level 3 (0.34 – 0.66) as quoted from Table 1.

**Discounting**

Setting the value of life-years higher today than the value of the future healthy years is discounting. It is an economic concept that individuals preferred benefits more today than in future [12]. A total discounting function at any age x was given in equation 4.

$$G(x) = e^{-rx} \quad (4)$$

Where $r$ was the discount rate

**Age Weighting**

When dealing with Disability Adjusted Life Years (DALYs), age weighting in humans meant that the life years of children and old people are counted less than other ages. In animals, the years of healthy life lived during matured ages are valued over early and late ages. In cattle, age weighting determined the age at which cattle started and stopped being useful in terms of milk, meat, draught power, manure, social status, dowry and cultural ceremonies. Since cattle are more productive at a particular age than others, age weighting meant that cattle life years are counted differently [10]. The productive age was expressed mathematically in equation 5.

$$R(x) = \beta_1 x e^{-\beta_2 x^2} \quad (5)$$

Where x was the cattle's age, while β1 and $\beta_2$ were parameters of the age-weighting function.

**YLL and YLD for PALYs using Basic Formula**

$$YLD \text{ for cattle} = N_i x D_w x I \quad (6)$$

Where $N_i$ was the number of incident cases of anthrax, $D_w$ was the disability weight of anthrax, and I, the average duration of the disability.

$$YLL \text{ for cattle} = N_d x L \quad (7)$$

$N_d$ was the number of deaths, and L, the standard life expectancy at the age of death.

**YLD and YLL for PALYs with Discounting**

The *YLD* was obtained by multiplying *YLD* for the basic formula with discounting function in eq. (4) to give equation 8:

$$YLDs \text{ for cattle} = \int_{ai}^{ai+I} NiDw e^{-r(x-ai)} dx$$

(8)

Integrating eq. (8) we got,

$$YLD = \frac{N_i D_w [1-e^{-rI}]}{r} \quad (9)$$

Where r was the discount rate.

*YLL* was obtained by modifying equation 8, replacing average duration *I* by standard life expectancy at the age of death *L*, setting $D_w$ to one and replacing $N_i$ the number of incident cases by $N_d$ the number of deaths to yield equation 10.

$$YLLs \text{ for cattle} = \int_{ai}^{ai+L} Nd e^{-r(x-ai)} dx$$

(10)

Integrating eq. (10) we get

$$YLL = \frac{N_d [1-e^{-rL}]}{r} \quad (11)$$

Where $N_d$ was the number of deaths, *r* was the discount rate, and *L*, the life expectancy.

**YLD and YLL for PALYs with Both Discounting and Age Weighting**

Both the discounting function from eq. (4) and age weighting function eq. (5) were incorporated in the PALY formula. The *YLDs* value of any disability weight ($D_w$) with discounting function, age-weighting function and number of diseases cases ($N_i$), was given by:

$$YLDs \text{ for cattle} = N_i \ x \ D_w \ x \ G(x) \ x \ R(x)$$

(12)

Where *R*(*x*) was the age weighting function.

Combining eq. (4) and eq. (5) into Eq. (12), we got:

$$YLDs \text{ for cattle} = \int_{ai}^{ai+I} NiDw\beta 1 x e^{-\beta 2x2} e^{-r(x-ai)} dx \quad (13)$$

After integrating eq. (13) it became:

(14)

$$_w\beta_1 e^{a_i r} \left[ \sqrt{\pi} r e^{\frac{r^2}{4\beta_2}} \left( \frac{erf(2\beta_2(a_i+I)+r)+erf\left(\frac{2\beta_2 a_i+r}{2\sqrt{\beta_2}}\right)}{4\sqrt{\beta_2^3}} \right) \right.$$

$$\left. \frac{(a_i+I)+r)_{+e^{-a_i(\beta_2 a_i+r)}}}{} \right) \Bigg]$$

Where $N_i$ was the number of incident cases for anthrax, $D_w$, the disability weight, $I$, the average duration of disability, $r$; the discount rate, ai was the age of onset and erf the error function with $\beta_1$ and $\beta_2$ being 0.2332 and 0.01 respectively, adapted from Salih [10].

By replacing the duration of disease $I$, with standard life expectancy ($L$), age of onset ($a_i$) with the age of death ($a_d$), and setting the disability weight to one in equation 13, we got:

$$YLL \text{ for cattle} = \int_{ad}^{ad+L} Nd\beta 1 \, xe^{-\beta 2x} \, e^{-r(x-ad)} \, dx \quad (15)$$

Integrating 15, we got:

$$\boldsymbol{YLL} = N_d \beta_1 e^{a_d r} \left[ \sqrt{\pi} r e^{\frac{r^2}{4\beta_2}} \left( \frac{erf(2\beta_2(a_d+L)+r) + erf\left(\frac{2\beta_2 a_d + r}{2\sqrt{\beta_2}}\right)}{4\sqrt{\beta_2^3}} \right) + \left( \frac{-e^{-(a_d+L)(\beta_2(a_d+L)+r)} + e^{-a_d(\beta_2 a_d + r)}}{2\beta_2} \right) \right]$$

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Where $N_d$ was the number of deaths from anthrax, $L$, the average duration of disability, $a_d$ was age at death, r was the discount rate equal to 0.13, $\beta_1$ and $\beta_2$ were 0.2332 and 0.01, respectively all adapted from Salih [10].

**Ethical Consideration**

Ethical approval was obtained from the University of Zambia Biomedical Research Ethics Committee (UNZAREC) with clearance number REF. 714-2019. Both written and verbal consent was obtained from participants. The purpose of the study was explained to each participant verbally using English, Silozi and Chinyanja languages.

**Results**

The most commonly reported reasons for keeping cattle were draught power, manure, milk and transport, while sales, meat consumption, social status, dowry and cultural ceremonies were the least. When it came to mortality, diseases were ranked as the number one cause of cattle mortality, followed by theft. Drought, old age, accidents, and crocodile attacks were among the least in ranking the causes of this mortality. Table 2 shows that anthrax, lumpy skin and foot and mouth disease were ranked as the top among diseases that caused cattle mortality in the three districts of Mongu, Nalolo and Limulunga. Bovine viral diarrhoea and East Cost fever were the least.

The most productive age for cattle in terms of meat consumption, meat production, sales, cultural ceremonies and transport was 4 years, while the least productive age for these activities was 10 years. At 3 years, cattle were most productive for draught power and least productive at 10 years. As for dowry and social status, cattle became more productive for these activities at 2 years and least productive at 9 and 10 years, respectively (Figure 1 and 2).

**Estimating Societal Disease Burden with PALYs Considering Two Case Scenarios**

**Case 1: PALYs Lost due to immediate death**

The following information was used when calculating PALYs, under case 1.

a. Years lost due to disability (*YLD*) were 0 (since there was an immediate death of an animal).

b. Years lost due to premature mortality (*YLL*) had the following parameters:
   i. $a_d$ =3 (year of death)
   ii. $d$ = 1 (disability weight cause animal died)
   iii. $I$ =0 years (years with disability)
   iv. $r$ =0.13 (the discount rate)
   v. $\beta_1$ and $\beta_2$ are 0.2332 and 0.01 respectively (constants)
   vi. $e$ = 2.718

**Case 2: PALYs Lost due to death after disability**

The following information was used when calculating PALYs under case 2.

a. Years lost due to disability (YLD) were 0 (since there was an immediate death of an animal).
   i. $a_i$ =3 (year of onset/year when disability starts)
   ii. $I$ =2 days = 0.0055 years (years with disability)
   iii. $d$ = 0.34, 0.5 and 0.66 for cows bulls and oxen respectively (disability weights)
   iv. $r$ =0.13 (the discount rate)
   v. $\beta_1$ and $\beta_2$ are 0.2332 and 0.01 respectively (constants)
   vi. $e$ =2.718

b. Years lost due to premature mortality (YLL) had the following parameters:
   i. $a_d$ =3years and 2 days = 3.0055 years (year of death for animal)
   ii. $L$=12, 9 and 10 for cows, bulls and oxen, respectively (life expectancy at death)
   iii. $d$ = 1 (disability weights since the animals die)
   iv. $r$ =0.13 (the discount rate)
   v. $\beta_1$ and $\beta_2$ are 0.2332 and 0.01 respectively (constants)

In both cases 1 and 2, the number of incident cases (N*i*) of 186 was derived from the total deaths annually from the collected data. This was used as a proxy for the number of cattle that suffered from the disease annually. Since these deaths were not distinguished by animal type but generalised as cattle, this value of 186 was used as a number of incident cases for all the three categories (cows, bull or oxen).

**Estimating Societal Disease Burden of Anthrax when there is an Immediate Death of an Animal from Anthrax**

Table 3 shows the PALYs results when there is an immediate death of an animal across all the three categories. These are PALYs without discounting and age weighting, with discounting and with both discounting and age weighting. Results show that the PALYS are more for the category of without discounting and age weighing for all the three types of animals, cow bull and oxen with PALYs being 12.00 years per cow (2232.00 years for 186 cows), 9.00 years per bull (1674.00 years for 186 bulls) and 10.00 years per oxen (1860.00 years for 186 oxen). These are followed by the category of discounting with PALYs for cow, bull and oxen being 6.0759 years per cow (1130.11 years for 186 cows) , 5.3049 years per bull (986.71 for 186 bulls) and 5.5959 years per oxen (1040.84 years for 186 oxen) respectively. The least PALYs are obtained for the category of both discounting and age weighting with PALYs of 5.0465 years per cow (938.64 years for 186 cows), 4.6453 years per bull (864.03 years for 186 bulls) and 4.8249 yeas per oxen ( 897.43 for 186 oxen) for cow, bull and oxen respectively. In all these three categories of calculating PALYs, most of the PALYs were lost in cows seconded by oxen and lastly, in the bulls.

**Estimating Societal Disease Burden of Anthrax when there is a Disability before Death of an Animal from Anthrax**

Table 4 shows the PALYs when an animal lived with a disability before dying. The PALYs for a cow were 12.0019 years per cow (2232.35 years for 186 cows), 6.0759 years per cow (1130.4594 for 186 cows) and 5.0500 years (939.2943 for 186 cows) for without discounting and age weighting, with discounting and with both discounting and age weighting respectively. The PALYs for a bull were 9.0027 years per bull (1674.51 years for 186 bulls), 5.3076 years per bull (987.2152 years for 186 bulls) and 4.6494 years per cow (864.7931 years for 186 bulls) for without discounting and age weighting, with discounting and with both discounting and age weighting respectively. For the oxen, the PALYs were 10.0036 years per oxen (1860.67 for 186 oxen), 5.5995 years per oxen (1041.5115 for 186 oxen) and 4.8272 years per oxen (897.8623 for 186 oxen) for without discounting and age weighting, with discounting and with both discounting and age weighting respectively. In all the three categories of calculating the PALYs, most of the productivity life years are lost when there is no discounting and age weighting, seconded by the one with discounting and lastly, the one with both discounting and age weighting.

**PALYs Calculation on Mongu, Nalolo and Limulunga District Populations with both Discounting and Age Weighting**

Table 5 showed the total societal anthrax burden (PALYs) for Mongu, Nalolo, Limulunga districts in the case where an animal died after disability. The total cattle population for these three districts was 135,000 (55,000 from Mongu, 50,000 from Nalolo, 30,000 from Limulunga districts). This total comprised every cattle type. The total population of animals per district was obtained from the veterinary offices for each respective district. The herd structure used was developed by Lubungu, which stated that 36%, 5%, and 28% were the herd composition for cows, bulls, and oxen, respectively [9]. This structure yielded 48,600 cows, 6, 750 bulls, 37, 800 oxen, totaling 93150 cattle. The difference of 41850 from the total cattle population of 135,000 from the three districts was approximately for calves, heifers and steers. Anthrax caused a total of 459,280.9 These PALYs in the three districts of Western Zambia were calculated using the category of both discounting and age weighting.

**Discussion**

This study aimed at estimating the societal disease burden of anthrax among cattle communities of the Western Province of Zambia using PALYs. Reasons given by participants for keeping cattle were draught power, manure, milk and transport, while sales, meat consumption, social status, dowry and cultural ceremonies were the least. Two case scenarios were considered for this study. The first case was that where an animal dies immediately after being infected by anthrax, while the second case was where the animal suffered a disability before death. The age of onset for the disease was three years and lasted for an average duration of two days (0.0055 years) after which the animal died in the second case scenario. In this same second case scenario, the total PALYs lost were 5768 when the method without discounting and age weighting was used, 3159 total PALYs lost when the method with discounting only was used, and 2702 total PALYs when a method of both discounting and age-weighting was used. Discounting was included to prevent excessive giving weights to deaths at younger ages. The weighting function dictated the pattern of variation for a disease with a short duration. This was because PALYs are decreased for such a disease, especially if it started at very early or older ages of life [9].

From the results obtained, considering age weighting and discounting, approximately a cow lost about 34% of productivity years of its life span due to anthrax, a bull lost 39% of productivity life years of its life span while an oxen lost about 37% of productivity years of its life span. This shows that a bull lost most years of productivity, seconded by oxen, and lastly, a cow a finding which is in agreement with a study done by Mwila et al., on the productivity years lost due to ECF in the Southern Province of Zambia, which showed that a bull suffered the most loss of years of productivity of its life span with 49% seconded by the oxen, and lastly, the cow [10] . These finding agree with the study done by Salih in South Africa on modeling the impact of cattle diseases, specifically tick and tick borne diseases. It was also found that bulls suffered the most loss when it came to productivity life years with the loss of productivity life years being 35% [12]. With this development, we, therefore, argue that transportation, draught power, sells as well as socio status were the most affected as these are usually performed by the bull. These productivity losses for all three types of animals are reduced to almost 0% with the introduction of effective anthrax control measures. The effective anthrax control measures include mass vaccination of livestock, quarantine of infected animals, burning or burying animal carcasses and community sensitisation [5]. Therefore, it is vital to encourage the farmers to vaccinate their animals and sensitise them on how to control and treat the animals in case of anthrax infection to improve cattle productivity and lessen the disease burden of anthrax. Further, the findings show that anthrax disease caused 459, 280.90 losses in quality years of life lived by cattle due to morbidity and premature mortality, resulting in loss of productivity when control measures are not applied. The age group which was mainly affected by anthrax was three years. Anthrax, an acute disease, brought about a significant loss of quality of life for the animals even if treated, resulting mainly from premature mortality. This translated into a loss of productivity adjusted life years (PALYs). This loss happened to all types of cattle (cow, bull or oxen) regardless of the category of PALYs used. The products lost during these years included draught power, milk, manure and meat. When control measures of anthrax are put in place, the PALYs lost reduced significantly, increasing the productivity of the animals. The quality of life is expected to improve significantly when control measures are applied like vaccination. With the control measures in place, these animals are expected to live their full life expectances of 15, 12 and 13 years for cows, bulls, and oxen, assuming that no other health conditions are affecting them.

## Conclusion

Anthrax brought about a loss of productivity for the cattle. From this study, the PALYs lost for the three districts of Zambia, namely; Mongu, Nalolo, and Limulunga, were estimated to be 459,280.90. These findings were essential for measuring animal health outcomes in terms of PALYs. These findings implied that anthrax negatively affected livestock production due to significant loss of healthy years of life and loss of quality of life. From these loses, bulls lost most of the productivity years of their life span and we, therefore, argue that transportation, draught power, sells as well as social status were the most affected as these are usually performed by the bull. Since cattle have many values to resource-poor communities, including direct food production, their use in agricultural production (such as draft power or sources of manure), as a deposit of wealth, and valuable cultural benefits, loss of livestock through disease can impact negatively in these areas. Furthermore, cattle have a wide range of functions; for example, food, labour, asset, transport, and source of fertilisers are related to the productivity of the cattle. Therefore, it is important to minimise the loss of cattle productivity through morbidity and mortality. Different intervention programmes for the same disease can be compared in cost-effective analysis using PALYs as one of the tools. In this study, the PALYs model was used to assess the burden of anthrax disease on cattle production. Therefore, it is recommended that the societal burden of diseases is also applied on top of other existing methods used to assess the impact of diseases on animals to enable policymakers to have a complete and comprehensive picture of the impact.

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**Table 1: Definition of Disability Weight ($D_w$) for Cattle**

| Levels | Description | $D_w$ |
|---|---|---|
| 1 | 1. Beef production [(500 − 700kg for oxen), (300 − 516kg for bulls), (320 − 440 kg for cows)].<br>2. Milk production [5 − 6 litres per day].<br>3. Draught power [3 − 5hrs for cows, 5 − 6hrs for oxen].<br>4. Social status [acceptable].<br>5. Dowry payment [acceptable].<br>6. Cultural ceremonies [acceptable]. | 0 |
| 2 | 1. Beef production [(420 − 499kg for oxen), (260 − 299kg for bulls), (280 − 319kg for cows)].<br>2. Milk production [3.5 − 4.9 litres per day].<br>3. Draught power [2 − 3hrs for cows, 3 − 4hrs for oxen].<br>4. Social status [not very acceptable for the reason of loss of condition].<br>5. Dowry payment [not very acceptable for the reason of loss of condition].<br>6. Cultural ceremonies [not very acceptable for the reason of loss of condition]. | 0.01 − 0.33 |
| 3 | 1. Beef production [(360 − 419kg for oxen), (220 − 259kg for bulls), (200 − 279kg for cows)].<br>2. Milk production [2 − 3.4 litres per day].<br>3. Draught power [1 − 2hrs for cows, 2 − 3hrs for oxen].<br>4. Social status [not acceptable for the reason of being diseased].<br>5. Dowry payment [not acceptable for the reason of being diseased].<br>6. Cultural ceremonies [not very acceptable for the reason of being diseased] | 0.34 − 0.66 |

| | | |
|---|---|---|
| 4 | 1. Beef Production [(300 − 359kg For Oxen), (180 − 219Kg For Bulls), (140 − 199 Kg For Cows)].<br>2. Milk Production [1 − 1.9 litres per day].<br>3. Draught Power [0 − 1hrs For Cows, 1 − 2hrs For Oxen].<br>4. Social Status [not Acceptable For Reason Of Being Thin And Diseased].<br>5. Dowry Payment [not Acceptable For Reason Of Being Thin And Diseased].<br>6. Cultural Ceremonies [not Very Acceptable For Reason Of Being Thin And Diseased] | 0.67 − 0.99 |

**Table 2: Diseases Causing Cattle Mortality**

| | Anthrax | Lumpy Skin Disease | Foot and Mouth Disease | Bovine Viral Diarrhea | East Coast fever |
|---|---|---|---|---|---|
| N (Count) | 197 | 298 | 248 | 196 | 190 |
| N (Percent) | 65% | 97% | 81% | 64% | 62% |
| Mode | 1 | 1 | 1 | 5 | 5 |

**Table 3: Calculation of PALYs for all Categories When There is an Immediate Death of Animal**

| Calculation for PALYS lost due to immediate death of an animal | | | | |
|---|---|---|---|---|
| **Animal** | **Parameter** | **Without iscounting and age weighting** | **With discounting** | **With both discounting and age weighting** |
| **Cow** | ***Ni/Nd*** | 186 | 186 | 186 |
| | ***ai*** | 3 | 3 | 3 |
| | **I (days)** | 0 | 0 | 0 |
| | ***Dw*** | 1 | 1 | 1 |
| | **YLD** | 0 | 0 | 0 |
| | **L** | 12 | 12 | 12 |
| | **YLL** | 2232.00 | 1130.11 | 938.64 |
| | **PALYs** | 2232.00 | 1130.11 | 864.64 |
| **Bull** | ***Ni/Nd*** | 186 | 186 | 186 |
| | ***ai*** | 3 | 3 | 3 |
| | **I (days)** | 0 | 0 | 0 |
| | ***Dw*** | 1 | 1 | 1 |
| | **YLD** | 0 | 0 | 0 |
| | **L** | 9 | 9 | 9 |
| | **YLL** | 1674.00 | 986.71 | 864.03 |
| | **PALYs** | 1674.00 | 986.71 | 864.03 |
| **Oxen** | ***Ni/Nd*** | 186 | 186 | 186 |
| | ***ai*** | 3 | 3 | 3 |
| | **I (days)** | 0 | 0 | 0 |
| | ***Dw*** | 1 | 1 | 1 |
| | **YLD** | 0 | 0 | 0 |
| | **L** | 10 | 10 | 10 |
| | **YLL** | 1860.00 | 1040.84 | 897.43 |
| | **PALYs** | 1860.00 | 1040.84 | 897.43 |

**Table 4: Calculation of PALYs for all Categories When There is a Disability Before Death**

| Calculation for PALYS lost after a disability followed by death of an animal | | | | |
|---|---|---|---|---|
| **Animal** | **Parameter** | **Without discounting and age weighting** | **With discounting** | **With both discounting and age weighting** |
| **Cow** | ***Ni/Nd*** | 186 | 186 | 186 |
| | ***ai*** | 3 | 3 | 3 |
| | **I (days)** | 2 | 2 | 2 |
| | ***Dw*** | 0.34 | 0.34 | 0.34 |
| | **YLD** | 0.3465 | 0.3464 | 0.2212 |
| | **L** | 12 | 12 | 12 |
| | **YLL** | 2232.00 | 1130.1130 | 939.0731 |
| | **PALYs** | 2232.35 | 1130.4594 | 939.2943 |
| **Bull** | ***Ni/Nd*** | 186 | 186 | 186 |
| | ***ai*** | 3 | 3 | 3 |
| | **I (days)** | 2 | 2 | 2 |
| | ***Dw*** | 0.5 | 0.5 | 0.5 |
| | **YLD** | 0.5096 | 0.5094 | 0.3253 |
| | **L** | 9 | 9 | 9 |
| | **YLL** | 1674.00 | 986.7058 | 864.4677 |
| | **PALYs** | 1674.51 | 987.2152 | 864.7931 |
| **Oxen** | ***Ni/Nd*** | 186 | 186 | 186 |
| | ***ai*** | 3 | 3 | 3 |
| | **I (days)** | 2 | 2 | 2 |
| | ***Dw*** | 0.66 | 0.66 | 0.66 |
| | **YLD** | 0.6727 | 0.6724 | 0.4294 |
| | **L** | 10 | 10 | 10 |
| | **YLL** | 1860.00 | 1040.8391 | 897.4329 |
| | **PALYs** | 1860.67 | 1041.5115 | 897.8623 |

**Table 5: PALYs Calculation on Mongu, Nalolo, Limulunga, Mumbwa and Mfuwe Cattle District Populations with both Discounting and Age Weighting**

| Cattle | Population | YLD (years) | YLL (years | PALYs (years) |
|---|---|---|---|---|
| Cows | 48,600 | 57.8 | 245,370.7 | 245,428.5 |
| Bulls | 6,750 | 11.8 | 31,371.8 | 31,383.6 |
| Oxen | 37,800 | 87.3 | 182,381.5 | 182,468.8 |
| **Total** | **93150** | **156.9** | **459,124.0** | **459,280.9** |

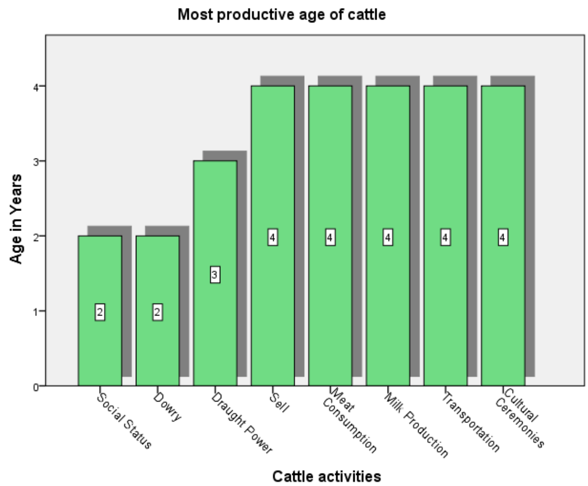


**Figure 1: The Most Productive Age for Cattle and their Respective Activities**

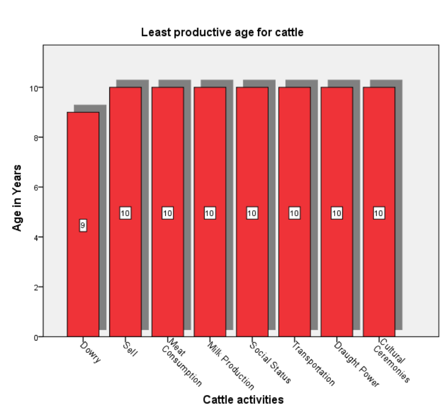


**Figure 2: The Least Productive Age for Cattle and their Respective Activities**