Modelling Societal Burden of AMU/AMR

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Overview

- AMR burden in humans has been covered to some extent
  - Increased healthcare costs,
  - Prolonged duration of hospitalization,
  - Death,
  - Incidence (Poudel et al 202).
- We conducted a systematic review in animal health
  - Little data available other than increased costs of antimicrobials, reduced productivity, diagnostic tests, mortality
- Hence the need for assessing the burden by integrating:
  - Animal Health Loss Envelop (AHLE) (Martins et al., 2024).
  - PALYs (modification of DALYs) (Salih et al 2023)

Animal Health Loss Envelope (AHLE)

- Metric to estimate the financial impact of AMU and AMR through 3 key parameters (Babo Martins et al., 2024).
  - Expenditure in animal health due to AMU.
  - Production losses due to mortality arising from AMR.
  - Production losses due to morbidity arising from AMR.
- AMR is a negative externality of AMU

Data needs & potential gaps

Data Category	What's Needed	Potential Data Gaps
Antimicrobial Use (AMU) Data	- Data on antimicrobial types and quantities used in livestock. - Retail price of antimicrobials.	- Lack of granular AMU data (e.g., dosages, duration, species-specific use). - Limited pricing data on antimicrobials.
AMR Frequency Measures	- Incidence and prevalence rates of AMR in livestock populations. E.g mastitis in livestock.	- Insufficient surveillance data at the required level of specificity.
Production Losses Due to Mortality	- Mortality rates linked to AMR infections. - Animal disposal costs.	- Limited data attributing mortality directly to AMR infections.
Production Losses Due to Morbidity	- AMR-related reductions in production efficiency, including: - Reduced feed conversion. - Slower growth rates. - Delayed selling or product withdrawal. - Increased premature culling & replacement costs. - Yield reductions (e.g., milk, meat, eggs). - Reproductive impacts (e.g., lower fertility).	- Scarcity of data linking AMR infections to production losses. - Limited long-term studies on AMR effects in different livestock systems.
Health Expenditure	- Costs of treating AMR-infected livestock, including: - Additional or second-line therapies. - More expensive diagnostic tests. - Veterinary services and farm labour. - AMR prevention and mitigation (e.g., biosecurity, vaccination, outbreak control).	- Lack of detailed data associating AMR cases with specific treatment costs. - Limited pricing data for second-line treatments and diagnostics.

What are DALYs

- DALYs = Disability Adjusted Life Years
- A common measurement unit for morbidity and mortality
- Facilitates comparisons of all types of health outcomes

How are DALYs constructed?

- A DALY is a health outcome measure with two main components
  - Quality of life reduced due to a disability
  - Lifetime lost due to premature mortality.
- DALYs can be expressed as follows:
  - **DALYs = YLD + YLL**

Modification of DALYS to Productivity Adjusted Life Years Using a Case of AMR-Mastitis in Commercial Dairy Farms

PALYs concept for cattle

- We reconfigured 4 parameters from standard DALYs model:
  - Standard lifespan,
  - Disability weight,
  - Discounting,
  - Age weighting.
- Questionnaire to capture information on these context-specific parameters

Standard lifespan (life expectancy)

- We used WHO standard life tables to calculate life expectancy
  - No. cows dying in each age of life e.g. at birth
  - Obtain information by asking total no. animals lost in a year & age at death
  - Calibrate on l_x table

- Where x= age group, n_x=no. cows at age_x, d_x=death rate at age_x, l_x-prob of survival at age_x, q_x= probability of dying at age_x, L_x= midpoint survival, ex=life expectancy at age_x

Table 3.1: Standard life expectancy for cattle (Cows)

x	n_x	$d_x = n_x - n_{x+1}$	$l_x = \frac{n_x}{n_0}$	$q_x = \frac{d_x}{n_x}$	$L_x = \frac{(l_x + l_{x+1})}{2}$	$T_x = T_{x-1} - L_{x-1}$	$e_x = \frac{T_x}{l_x}$
0	116	5	1.00	0.04	0.98	12.83	12.83
1	111	5	0.96	0.05	0.94	11.85	12.38
2	106	5	0.91	0.05	0.89	10.91	11.94
3	101	4	0.87	0.04	0.85	10.02	11.51
4	97	5	0.84	0.05	0.81	9.17	10.96
5	92	5	0.79	0.05	0.77	8.35	10.53
6	87	5	0.75	0.06	0.73	7.58	10.11
7	82	5	0.71	0.06	0.69	6.85	9.70
8	77	5	0.66	0.06	0.64	6.17	9.29
9	72	4	0.62	0.06	0.60	5.53	8.90
10	68	4	0.59	0.06	0.57	4.92	8.22
11	64	4	0.55	0.06	0.53	4.35	7.89
12	60	5	0.52	0.08	0.50	3.82	7.38
13	55	2	0.47	0.04	0.47	3.32	7.01
14	53	5	0.46	0.09	0.44	2.86	6.25
15	48	4	0.41	0.08	0.40	2.42	5.85

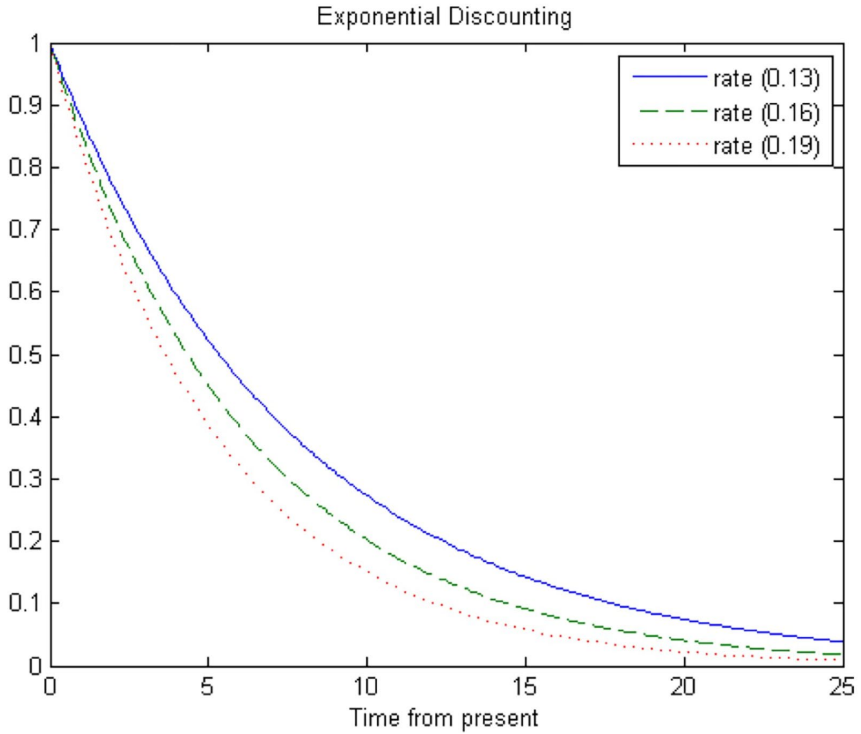
Disability weight

- Disability is inability to perform everyday tasks in a way that is usual for cattle
- Disability weight is a weight function that reflects severity of a cattle disease between 0 (perfect health) & 1 (equivalent to death)
- Each disability condition is assigned a number between 0 & 1, depending on severity of disease

Table 1: Definition of disability weight (Dw) for cattle according to Salih, 2014

Levels	Description	Dw
1	1. Beef production [(500 - 600kg for oxen), (300 - 516kg for bulls), (320 - 440 kg for cows)]. 2. Milk production [5 - 6 litres per day]. 3. Draught power [3 - 5hrs for cows, 5 - 6hrs for oxen]. 4. Social status [acceptable]. 5. Dowry payment [acceptable]. 6. Cultural ceremonies [acceptable].	0
2	1. Beef production [(400 - 499kg for oxen), (260 - 299kg for bulls), (280 - 319kg for cows)]. 2. Milk production [3:5 - 4:9 litres per day]. 3. Draught power [2 - 3hrs for cows, 3 - 4hrs for oxen]. 4. Social status [not very acceptable for the reason of loss of condition]. 5. Dowry payment [not very acceptable for the reason of loss of condition]. 6. Cultural ceremonies [not very acceptable for the reason of loss of condition].	0:01 - 0:33
3	1. Beef production [(300 - 399kg for oxen), (220- 259kg for bulls), (200 - 239kg for cows)]. 2. Milk production [2- 3:4 litres per day]. 3. Draught power [1 - 2hrs for cows, 2 - 3hrs for oxen]. 4. Social status [not acceptable for the reason of being diseased]. 5. Dowry payment [not acceptable for the reason of being diseased]. 6. Cultural ceremonies [not very acceptable for the reason of being diseased].	0:34 - 0:66
4	1. Beef production [(300 - 399kg for oxen), (220 - 259kg for bulls), (200- 239kg for cows)]. 2. Milk production [2 - 3:4 litres per day]. 3. Draught power [1 - 2hrs for cows, 2- 3hrs for oxen]. 4. Social status [not acceptable for the reason of being diseased]. 5. Dowry payment [not acceptable for the reason of being diseased]. 6. Cultural ceremonies [not very acceptable for the reason of being diseased].	0:67 -0:99

Discounting



1. Discounting effects on PALYs: A comparison of different rates.

- Same discount function (exponential decay) used in the DALYs model for human population
- But, change discount rate to be able to obtain the same effect of discounting in the number of years of life lost at a different time in the future

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

- Where: G(x) is a continuous discounting function at any age x and r>0 is the discount rate.

Age weighting

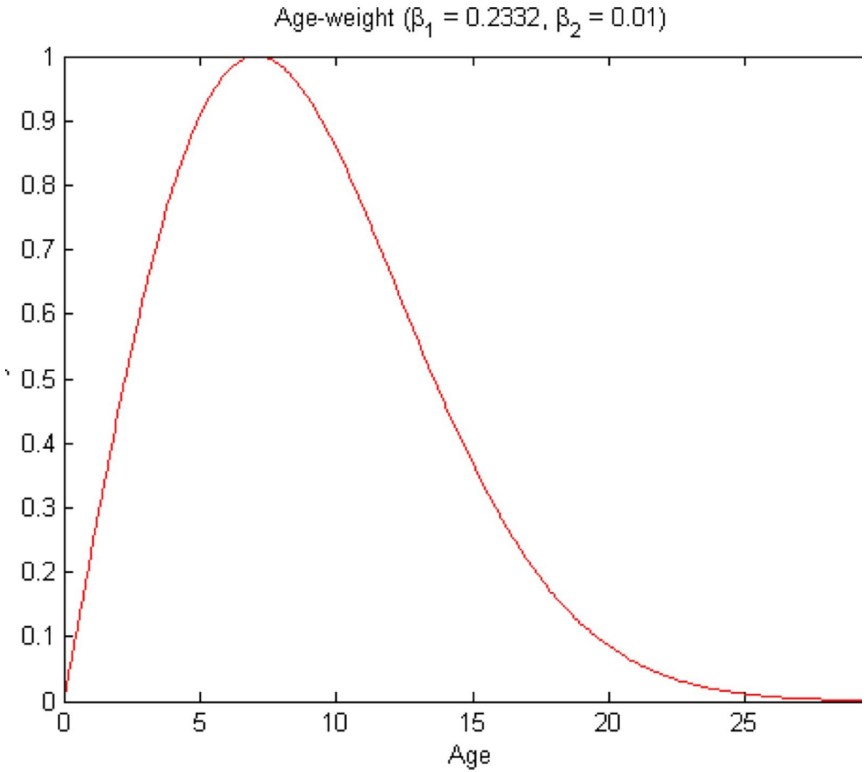
- We value years of life lived during productive ages reason being based on economic and social value
- The preference for productive ages can be expressed mathematically as

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

- Where x is the age of the cattle, while β_1 and β_2 are parameters of the age-weighting function

Age weighting…

- β1 determines the importance of age-weights
- β2 is an adjustment constant, chosen so that the introduction of age-weights does not alter the total number of years of life lost
- The value of β1 = 0.2332 and β2 = 0.01 used in the PALY calculation
- Data based on questionnaires



Calculation of PALYs for Cattle using 3 scenarios

1. Basic formula,
2. PALYS with discounting
3. PALYs with both Age weighting and Discounting

1. Basic Formula for PALYs

- $\mathbf{YLD_{cattle}} = N_i \times D_w \times I$
- $\mathbf{YLL_{cattle}} = N_d \times L$

- *Where;*
  - *(YLDs) years of life lived with Mastitis (AMR)*
  - *(YLLs) year of life lost due premature mortality- Mastitis (AMR)*

- Key
  - N_i = No. cows with Mastitis
  - N_d = No. death due Mastitis
  - **L** = Standard life expectancy at age of death
  - D_w = Severity of disease
  - i = Duration of the disease

2. PALYs with Discounting

- Derive the formula for YLD by multiplying the basic YLD formula with the discounting function
  - $\boldsymbol{YLD = \frac{N_i D_w [1 - e^{-rI}]}{r}}$
- Replace the average duration (I) by standard life expectancy at the age of death (L) to get YLL
  - $\boldsymbol{YLL = \frac{N_d [1 - e^{-rL}]}{r}}$

- Key to PALYs formula
  - N_i- the number of cows with ECF in each group.
  - r - discount rate
  - N_d - No. death in cattle due to AMR Mastitis.
  - L- standard life expectancy at age of death.
  - D_w - disability weight.
  - I- duration of the disease.

3. YLD With Age-weighting & Discounting

- $$YLD = N_i\, D_w\, \beta_1\, e^{a_i r}\left[\sqrt{\pi} r e^{\frac{r^2}{4\beta_2}}\left(\frac{erf(2\beta_2(a_i+I)+r)+erf\left(\frac{2\beta_2 a_i+r}{2\sqrt{\beta_2}}\right)}{4\sqrt{\beta_2^3}}\right)+\left(\frac{-e^{-(a_i+I)(\beta_2(a_i+I)+r)}+e^{-a_i(\beta_2 a_i+r)}}{2\beta_2}\right)\right]$$

- Where: N_i = No. incident cases, D_w = disability weight, I = duration of AMR Mastitis, r = discount rate, a_i = age of onset, erf = error function, β_1 & β_2 are 0.2332 and 0.01 respectively

3. YLL with Age-weighting & Discounting

- Replace duration of disease I with standard life expectancy (L), age of onset a_i with the age of death a_d

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

Reporting Results of PALYs and AHLEs

Reporting Results of PALYs

Table 2. PALYs for cows with $D_w = 0.33$.

Age group	N_i	a_i	I	D_w	YLD	N_d	a_d	L	YLL	PALYs
0–4	6	2	1	0.33	4.18	6	3	11.51	71.14	75.32
5–9	17	7	1	0.33	11.77	17	8	9.29	141.41	153.18
10–15	23	12	1	0.33	10.88	23	13	7.01	92.94	103.82
16–20	29	18	1	0.33	7.75	29	19	3.50	20.51	28.26
20 +	41	20	1	0.33	2.06	41	21	1.50	7.56	9.62
Total	116				36.64	116			333.56	370.20

Summarizing results

- We will have 3 categories of PALYs and compare
  - PALYs without AMR-Resistant Mastitis
  - PALYs with AMR-Resistant Mastitis
- Simulate PALYs with mitigation e.g. AM stewardship
- AHLE will be presented in monetary terms (financial cost analysis)
  - Compare cost of AMU without AMR-Mastitis & with AMR-Mastitis

Thank you for Listening

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