A Mathematical model for bovine brucellosis incorporating contaminated environment

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Introduction.

- *Brucellosis* is an infectious, contagious disease of animals and man caused by a bacterium of genus Brucella.
- It is a major zoonetic disease widely described in both humans and animals especially in developing countries.
- The disease causing organism is found in blood and urine of infected animals and is abundant in fetal fluids and membranes of infected aborting and delivering animals.
- *Brucellosis* is commonly transmitted to susceptible livestock by direct contact with infected animals or with an environment that has been contaminated with discharges from infected animals (Geoffrey *et al*., 2002).

• Aborted fetuses, placental membranes or fluids, and other vaginal discharges present after an infected animal has aborted or calved are all highly contaminated with infectious *Brucella* organisms (Al-Eissa *et al*., 2002).
• Wild carnivores pick these placentas and dropped fetuses and drag them along the grazing area as they eat them.
• This puts other animals that graze on these pastures at high risk of getting infected.
• In this paper, we discuss the indirect mode of transmission of brucellosis through contaminated environment.

Assumptions of the model

- Recruitment into the population is only via birth.
- There is homogeneous mixing in the cattle population.
- Population birth rate and natural mortality rate are constant.
- Population birth rate is greater than the natural mortality rate.
- Animals that show symptoms and test positive to *brucellosis* are slaughtered.
- Grazing space is so large such that the effect of congestion does not contribute on death rate of the animals.

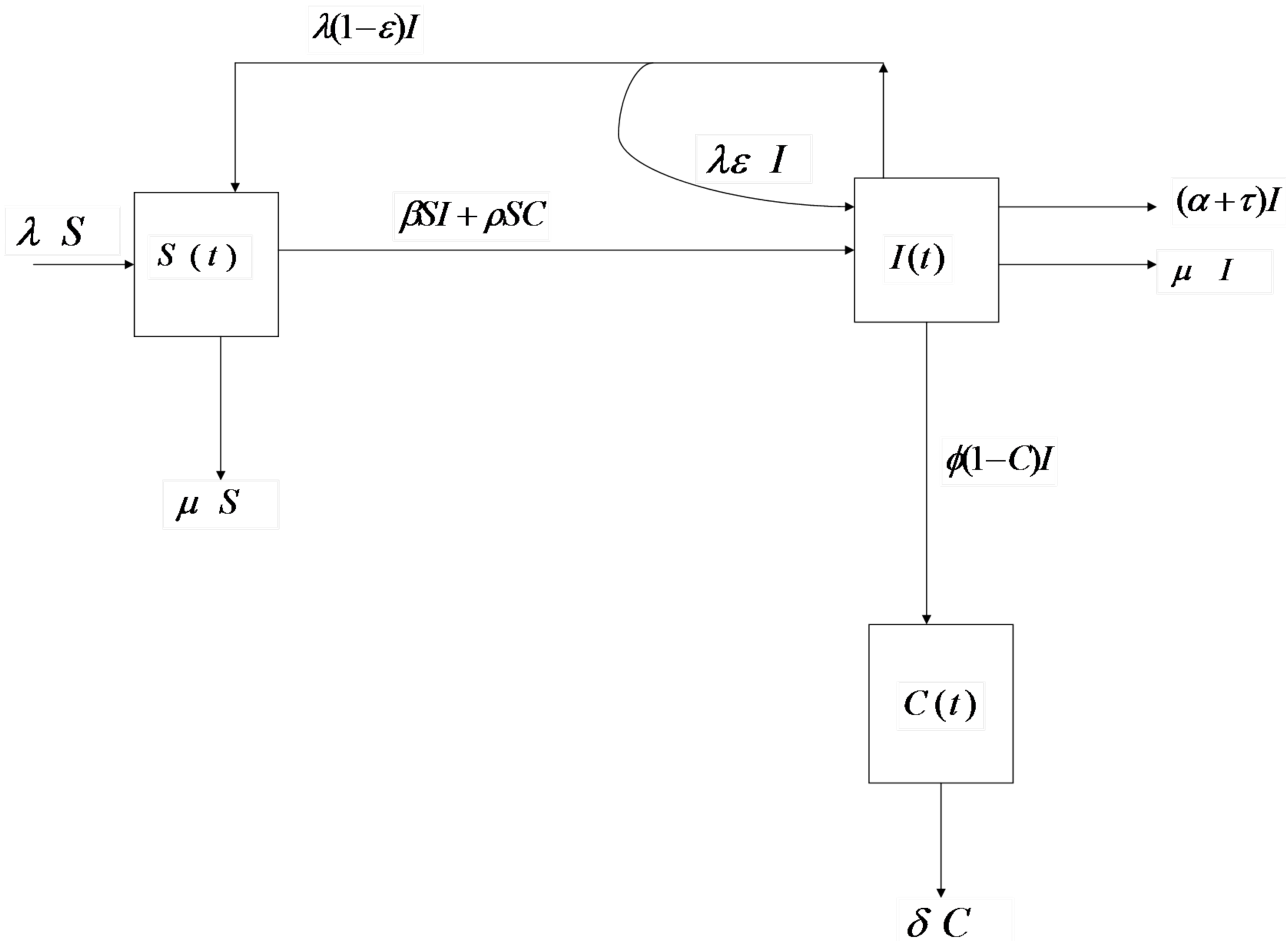
The variables

- $N(t)$the total population size of the animal hosts.
- $S(t)$the number of susceptible animal hosts at time t.
- $I(t)$the number of infected animal hosts at time t.
- $C(t)$the proportion of the habitant that is contaminated.

The parameters of the model

- α :disease-related death rate.
- β :the average contact rate/transmission rate.
- ϵ :the proportion of newborns (from infected mothers) that are infected.
- μ :natural death rate.
- λ :population birth rate.
- b :intrinsic growth rate.
- ϕ :Contamination rate of the environment.
- δ :decontamination rate of the environment.
- τ :the slaughter rate.
- ρ :indirect infection rate.

Compartmental diagram:



Model equations

$\frac{dS}{dt} = \lambda S + \lambda(1 - \epsilon)I - \beta SI - \rho SC - \mu S$
$\frac{dI}{dt} = \beta SI + \rho SC + \lambda \epsilon I - (\mu + \alpha + \tau)I$
$\frac{dC}{dt} = \phi(1 - C)I - \delta C$
which together with $S + I = N$ imply
$\frac{dN}{dt} = bN - (\alpha + \tau)I$
where $b = (\lambda - \mu)$.

- The term βSI corresponds to the direct transmission of brucellosis by contact between susceptible and infected animals.
- The indirect transmission is represented by the term ρSC.
- The production of the contaminant (bacteria) in the environment is described by the term $\phi(1 - C)$, which depends on the remaining fraction of uncontaminated environment $(1 - C)$.

The basic reproduction number (Ro)

•The next generation operator method is used to calculate the model basic reproduction number (R_0).

• This is given by $R_0 = \frac{\beta+\epsilon\lambda}{\mu+\alpha+\tau}$.

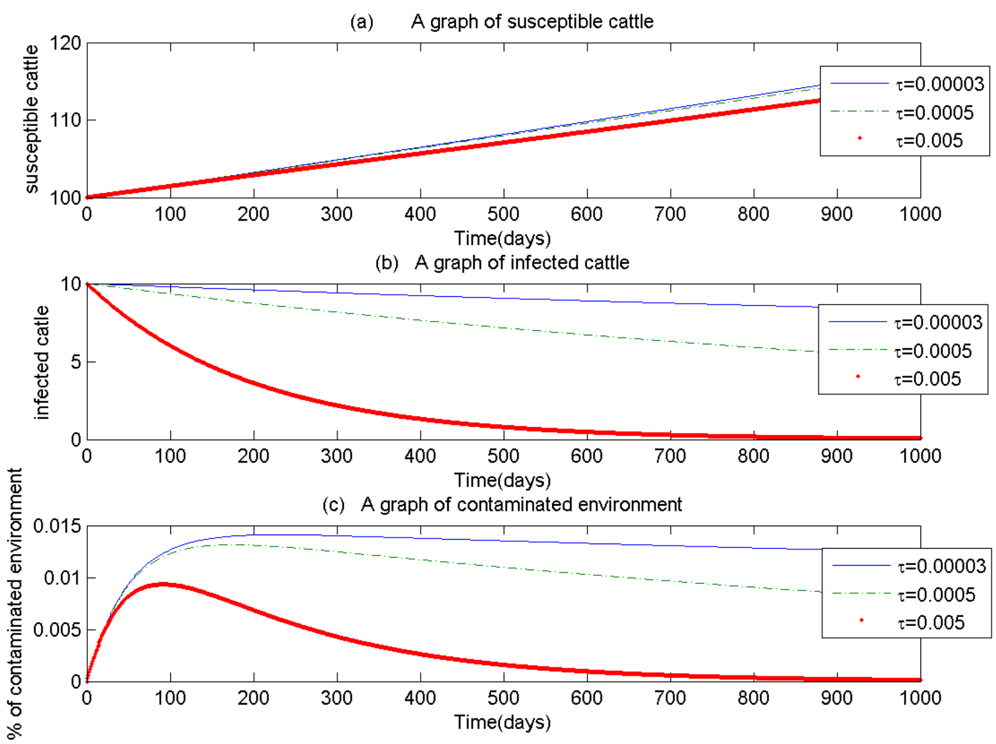
• It is expected that if $R_0 < 1$, then no *brucellosis* epidemic can develop in the cattle population, and if $R_0 > 1$, an epidemic can develop and become endemic in the cattle population.

Numerical Simulations

Parameter estimates for the model of brucellosis

Pmtrs	Value	Source.
λ	0.00075 per day	Zinsstang *et al*, 2005.
μ	0.00062 per day	Zinsstang *et al*, 2005.
α	0.00001 per day	Zinsstang *et al*, 2005.
ϵ	0.00165 per day	Bedr'Eddine *et al*, 2010.
b	0.00013 per day	Zinsstang *et al*, 2005.
δ	0.005 per day	Bedr'Eddine *et al*, 2010.
ϕ	Set per day	Assumed
β	Set per day	Assumed
τ	Set per day	Assumed

The effect of varying slaughter rate τ, of infected cattle on the epidemiological classes



Discussion

- The basic reproduction number R_0 was established in terms of the model parameters.
- It was noted that R_0 is independent of the contamination rate of the environment ϕ, but dependant on the contact rate β, the fraction of calves born infected $\epsilon\lambda$ and the slaughter rate τ.
- The basic reproduction number R_0 can be reduced to a value below one by having a higher value of slaughter rate of infected cattle.
- This reduces the contamination rate of the pastures that will eventually reduce abortions and the number of calves born infected since gestating animals feed on these pastures.

Recommendations

- Any cow that aborts should be tested for brucella and if it tests positive, then it should be slaughtered.
- More brucellosis diagnosis centers should be opened across the regions to ensure that many farmers have access to the facilities.
- Communal grazing should be avoided to reduce chances of contact with infected animals from other farms.

Further Development of the Model

The model developed can be extended to incorporate vaccination of susceptible population, immigrants and new borns, thus assess its role on the dynamics of brucellosis.

Thank You