MATHEMATICAL MODELING OF VISCERAL LEISHMANIASIS IN SUDAN

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Outline

INTRODUCTION

- Leishmaniasis is still one of the world's most neglected diseases, affecting largely the poorest of the poor, mainly in developing countries
- 350 million people are considered at risk of contracting leishmaniasis, and some 2 million new cases occur yearly
- Mathematical models can help describe and understand how the disease spreads, providing insights for better control and elimination strategies

Leishmaniasis : Definition and Transmission mode

- Leishmaniasis is a vector-borne infectious disease caused by protozoan parasites of the genus *Leishmania*.
- The disease is transmitted to humans through the bite of infected female phlebotomine sandflies.
- Sandflies acquire the parasite by feeding on infected hosts (e.g., humans or animals) and transmission occurs when the infected sandfly bites another host during a blood meal.
- Different forms of leishmaniasis include cutaneous, mucocutaneous, and visceral

Types of Leishmaniasis

Cutaneous Leishmaniasis (CL): Characterized by skin sores or ulcers at the site of the sandfly bite, often leading to scarring.

Figure 1: CL Example

Types of Leishmaniasis

Mucocutaneous Leishmaniasis (MCL): A severe form that destroys mucous membranes of the nose, mouth, and throat, causing disfigurement.

Figure 2: MCL Example

Types of Leishmaniasis

Visceral Leishmaniasis (VL): The most severe form, affecting internal organs like the spleen and liver, and can be fatal if untreated.

Figure 3: VL case example

Prevention and Treatment of Visceral Leishmaniasis

- Possibles prevention measures are related to vector control :
  - Use of Insecticide-Treated Nets (ITNs)
  - Indoor residual spraying (IRS)
  - Environmental management

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- Current Situation in Sudan :
  - VL has no vaccine available
  - Treatment relies on two major drugs:
    - Pentamidine: Commonly used for treatment
    - Sodium Stibogluconate: Another effective treatment option

Research Problem and Question

Background

Visceral leishmaniasis (VL), is a life-threatening disease that disproportionately affects vulnerable populations in Sudan. Despite ongoing control efforts, VL remains a significant public health challenge.

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Question

What level of treatment coverage is required to achieve the elimination of Visceral leishmaniasis in Sudan ?

Description of the model : Assumptions

- Vectors (sandflies) are not considered in the model, but are implicity included in the transmission rate
- There is no vertical transmission of the disease
- Our population is homogeneous
- The treatment is entirely efficace.
- There is no longlife immunity. Once someone get treated, he/she becomes susceptible agian after 2 years.

Description of the model : Key Parameters

- λ: Force of infection
- γ: Progression rate (1/latent period)
- ϵ: Proportion of the population receiving treatment;
- η: Proportion of the population developing chronic infection;
- μ: Natural mortality rate
- μ_c: Mortality rate due to chronic infection
- b: Birth rate
- α: Immunity loss rate

Description of the model : Model Diagram

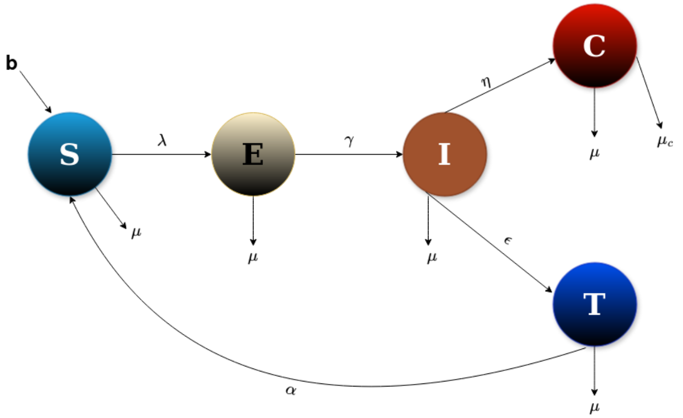

Figure 4: Model Diagram

Description of the model : PDEs

- **Susceptible (S)**:

$$\frac{dS}{dt} = bN - \lambda S + \alpha T - \mu S \tag{1}$$

- **Exposed (E)**:

$$\frac{dE}{dt} = \lambda S - \gamma E - \mu E \tag{2}$$

- **Infectious (I)**:

$$\frac{dI}{dt} = \gamma E - \epsilon I - \eta I - \mu I \tag{3}$$

Description of the model : PDEs

- **Treated (T)**:

$$\frac{dT}{dt} = \epsilon I - \alpha T - \mu T \tag{4}$$

- **Chronic (C)**:

$$\frac{dC}{dt} = \eta I - \mu_c C - \mu C \tag{5}$$

- **Constant Population**:

$$\frac{dN}{dt} = 0 \tag{6}$$

RESULTS AND ANALYSIS : Key Parameters Values

Table 1: Values and of Parameters and sources

Parameters	Values	Sources
Transmission rate	0.4	5
Initials Values :	$S = 1200, E = T = C = 0, I = 100$	Optional
Treatment rate (per day)	$[< 1\%, 2\%, 10\%]$	Optional
Immunity time	2 years	2
Infected Time	50 days	4

RESULTS AND ANALYSIS : Dynamics of VL

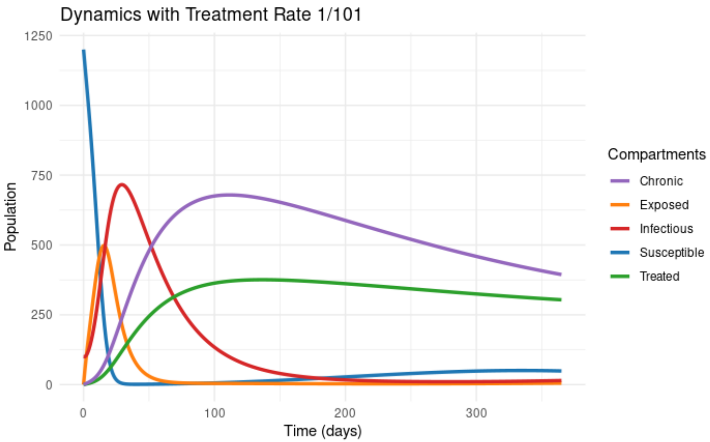

Figure 5: Dynamics of VL

RESULTS AND ANALYSIS : Dynamics of VL

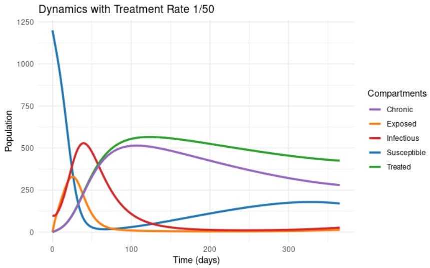

Figure 6: Treatment rate = 2%

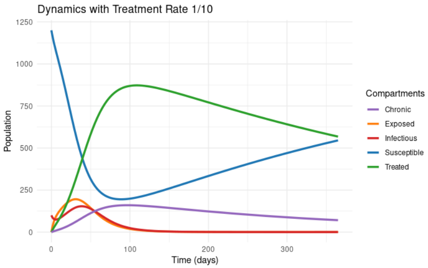

Figure 7: Treatment rate = 10%

RESULTS AND ANALYSIS : General Interpretations

Based on the previous graphs, we can deduce that :

- As we increase the treatment rate, we can remark that the number of people treated is increasing and the number of infectious people is decreasing. This mean that the treatment rate impacts significantly how the disease spread
- As we increase the treatment rate, we time needed before the infectious people decrease at almost zero is reducing; which means that by increasing the treatment rate, the disease will be eliminated more quickly.
- Known the limited ressources in Sudan, we will advise the Public health responsibles to admnistrate at least 10% of the treatment **per day** to be able to eliminate the disease almost three months.

CONCLUSION

- The dynamics reveal that increasing the treatment rate significantly enhances disease control by reducing the number of infectious and chronic cases and maintaining a larger susceptible population through effective management.
- These findings are essential for: public health planning ; allocating resources effectively to maximize treatment efficacy and minimizing the overall impact of the disease.

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Thank You!

Merci!

Questions are welcome.