



# SIRE Model

“The Influence of Education in Reducing the HIV Epidemic”

MATH 333 Differential Equations

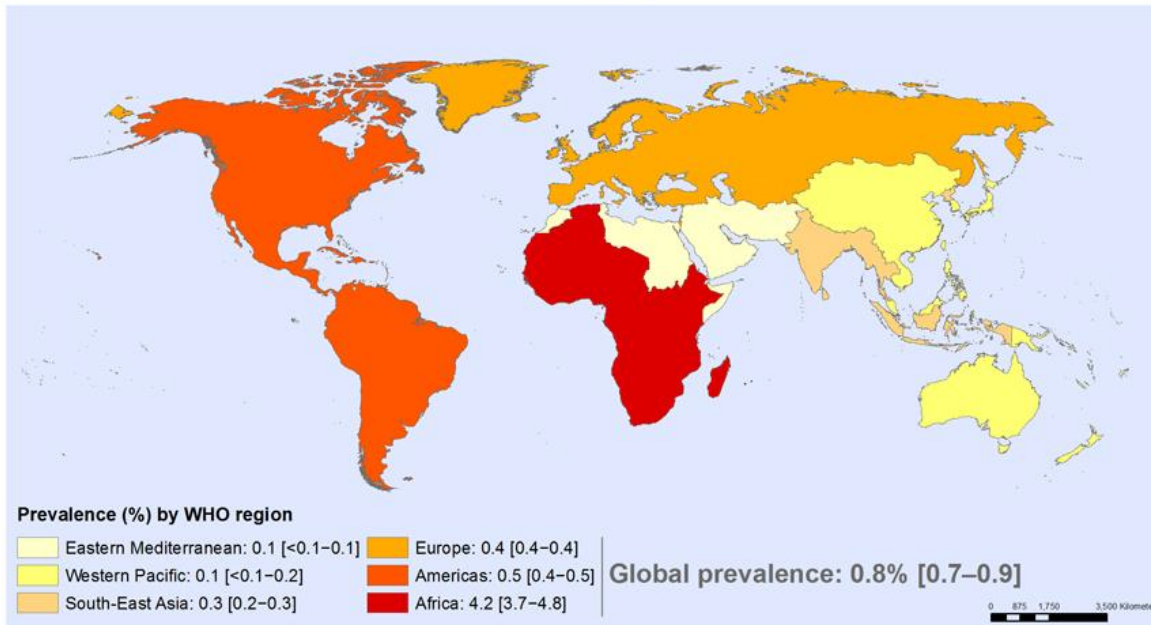
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# HIV in Uganda

Prevalence of HIV among adults aged 15 to 49, 2016  
By WHO region



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Data Source: World Health Organization  
Map Production: Information Evidence and Research (IER)  
World Health Organization

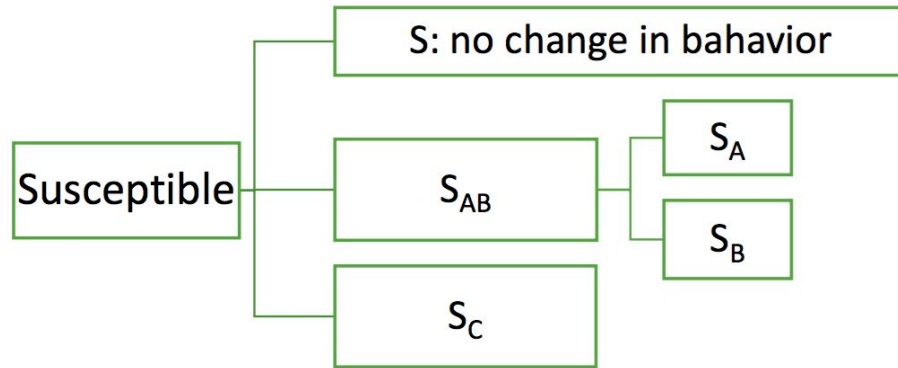


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# SIRE Model

Susceptible, Infected, Removed, Educated

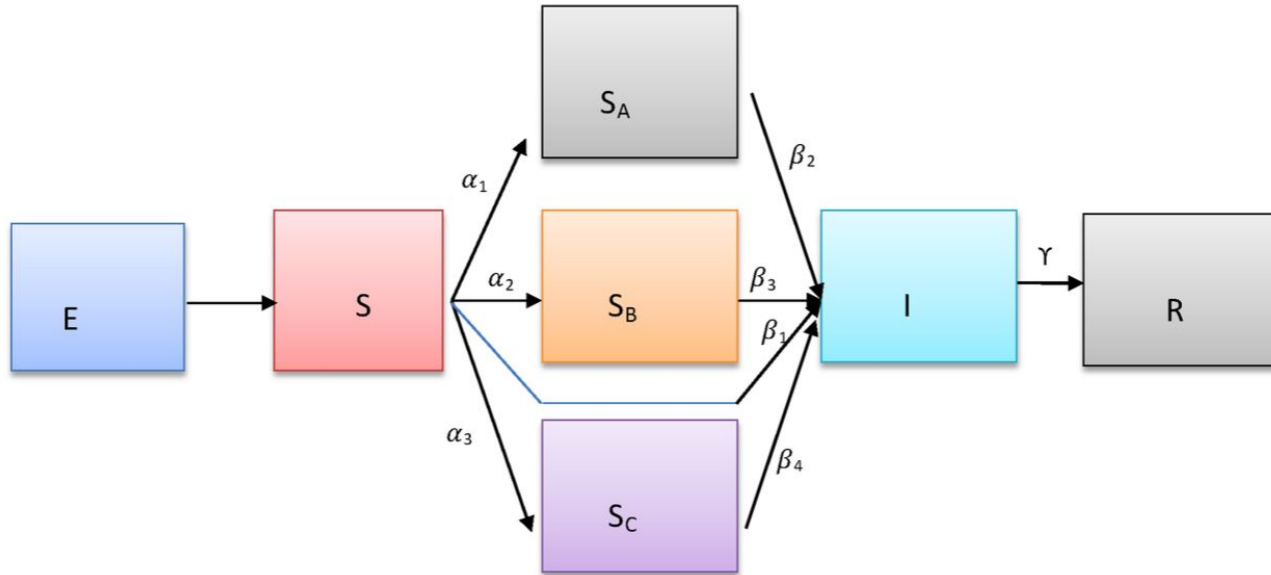


## ABC Program:

- **A**bstinence
- **B**eing faithful
- Use of **C**ondoms



## Schematics of SIRE model





## SIR

$$S' = -\beta SI + b(S + I) - dS, \quad I' = \beta SI - \gamma I, \quad R' = \gamma I,$$

## SIRE

$$S' = -\alpha_1 ES - \alpha_2 ES - \alpha_3 ES - \beta_1 SI + b(S + S_A + S_B + S_C + I) - dS,$$

$$S'_A = \alpha_1 ES - \beta_2 S_A I - dS_A \quad (\alpha_1 = 0.02),$$

$$S'_B = \alpha_2 ES - \beta_3 S_B I - dS_B \quad (\alpha_2 = 0.08),$$

$$S'_C = \alpha_3 ES - \beta_4 S_C I - dS_C \quad (\alpha_3 = 0.8),$$

$$I' = \beta_1 SI + \beta_2 S_A I + \beta_3 S_B I + \beta_4 S_C I - \gamma I,$$

$$R' = \gamma I,$$

$$E' = \frac{I}{I + S + S_A + S_B + S_C} r E (1 - E),$$



## SIRE Parameters

- The time period is from 1996-2007 (12 years)
- The researchers assumed that the rates  $b, d, r, \beta_1, \beta_2, \beta_3, \beta_4$ , and  $\gamma$  are all constant
- Using UN&WHO data they assigned:
  - $b=0.055$  (entering rate)
  - $d=0.0176$  (natural death rate)
  - $\gamma=0.14$  (death rate due to HIV)
- Then they assigned  $\beta_2, \beta_3$ , and  $\beta_4$  in terms of  $\beta_1$ , with  $0.0001 \leq \beta_1 \leq 0.1$ 
  - $\beta_2=0.01\beta_1$
  - $\beta_3=0.03\beta_1$
  - $\beta_4=0.4\beta_1$
- Lastly, they assigned  $0.2 \leq r \leq 2$

# Initial conditions

$$S(0) = 8.37$$

$$S_A(0) = 0$$

$$S_B(0) = 0$$

$$S_C(0) = 0$$

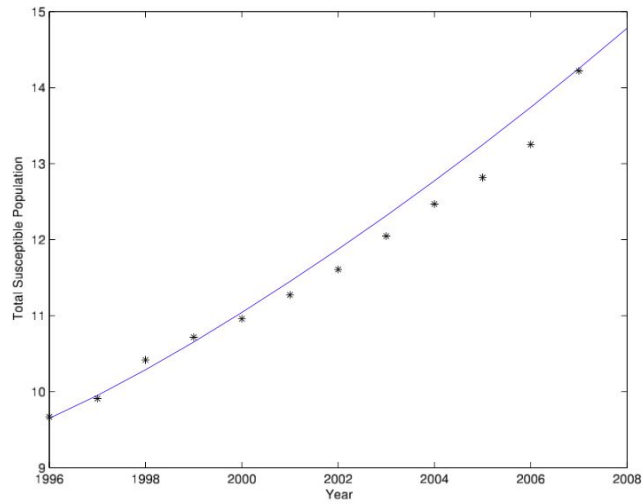
$$I(0) = 1.16$$

$$R(0) = 0.11$$

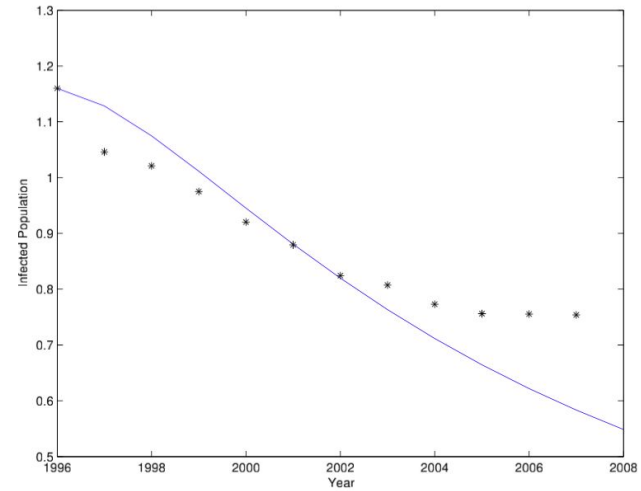
$$E(0) = 0.30$$

Year	Susceptible	Infected	Removed	Education
1997	9.99	1.046	0.1195	600/1,200
1998	10.42	1.021	0.1205	
1999	10.72	0.975	0.121	
2000	10.96	0.921	0.1215	700/1,200
2001	11.27	0.879	0.120	717/1,200
2002	11.61	0.824	0.118	
2003	12.05	0.807	0.113	
2004	12.47	0.773	0.104	778/1,200
2005	12.82	0.756	0.089	
2006	13.25	0.755	0.084	
2007	14.22	0.754	0.079	

**Table 1.** Historical data table (population numbers in millions).

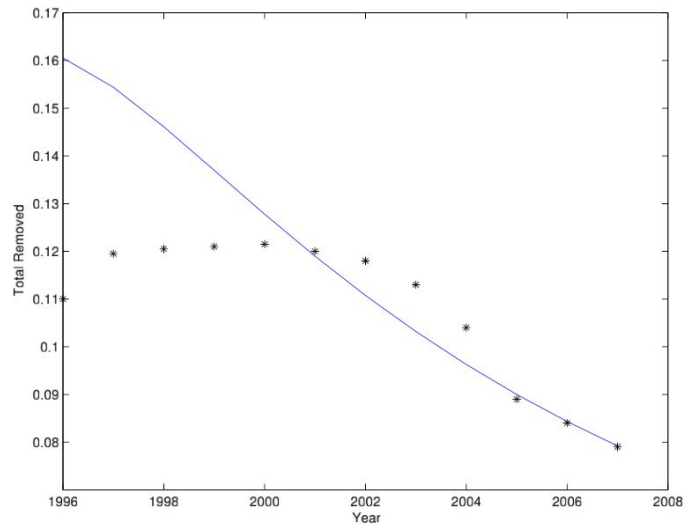


**Figure 2.** Susceptible population, in millions: model prediction (solid line) and data (\*).

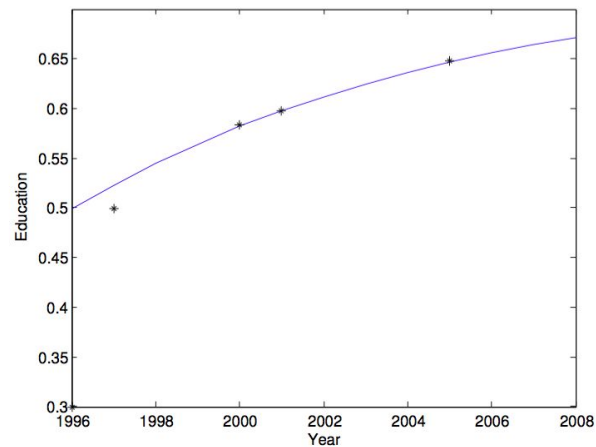


**Figure 3.** Infected population, in millions: model prediction (solid line) and data (\*).





**Figure 4.** Number of HIV related deaths, in millions: model prediction (solid line) and data (\*).



**Figure 5.** Education influence: model prediction (solid line) and data (\*).



# SIRE Model Simulation

Switch to MATLAB



# Conclusions

- The SIRE model generally captures the effect of education in reducing HIV in Uganda.
- Include more factors
  - Age
  - Gender
  - Stage of Disease
- Future Directions:
  - Include data after 2007 to further optimize the model
  - Expand the model to other countries
  - Change “Education” to other diseases and factors
    - Immunization
    - Malaria: access to mosquito nets

