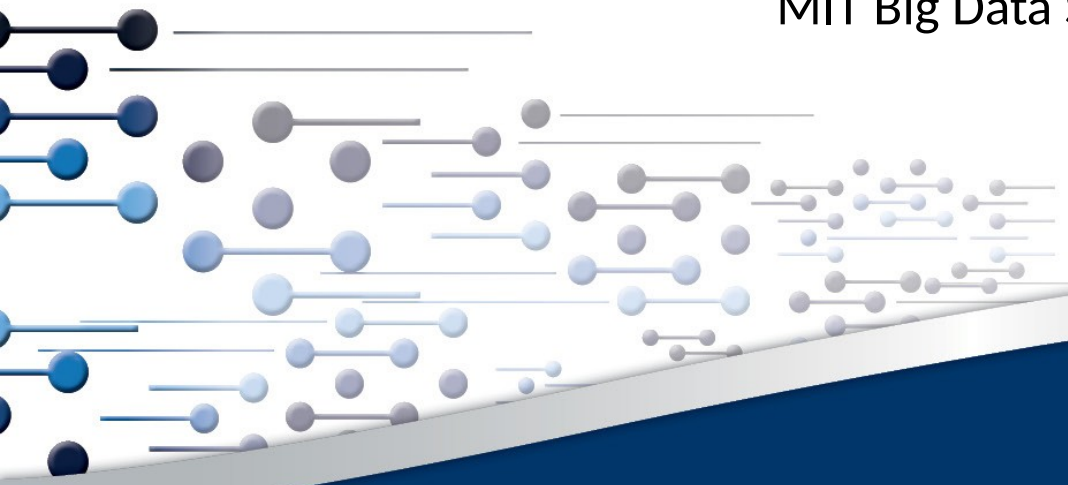
A mathematical model for the prospects of trachoma elimination through mass treatment targeted at children

Laing Lourens

BSc Mathematical Statistics (NMMU)

BSc Hons Biomathematics (Stell.)

MIT Big Data Science (UP)*



Trachoma

- What is it
  - Leading infectious cause of blindness
  - inside of the eyelid may be scarred so severely that the eyelid turns inward and the lashes rub on the eyeball, scarring the cornea

CSIR
our future through science

Trachoma

- How does it spread?
  - Direct contact with discharge from eyes, nose and throat of infected persons
  - Aerosolizaed pathogens from nasal infections
  - Active transfer of bacterium due to flies

- Prevalence
  - 21.4 million active infections
  - 1.2 million suffering blinding
  - Endemic in 53 countries as of 2012

Trachoma

- Prevalence
  - Highly prevalent in children
  - Children form core group for transmission

- WHO Eradication Strategy
  - GET 2020
  - SAFE strategy
  - Mass Drug Administration:
    Oral dose of Azithromycin (~95% efficacy)
  - ANNUAL treatment of ALL individuals if …

Problem Statement

- Can antibiotic treatment targeted at children alone eliminate trachoma infection from an entire community?

Data

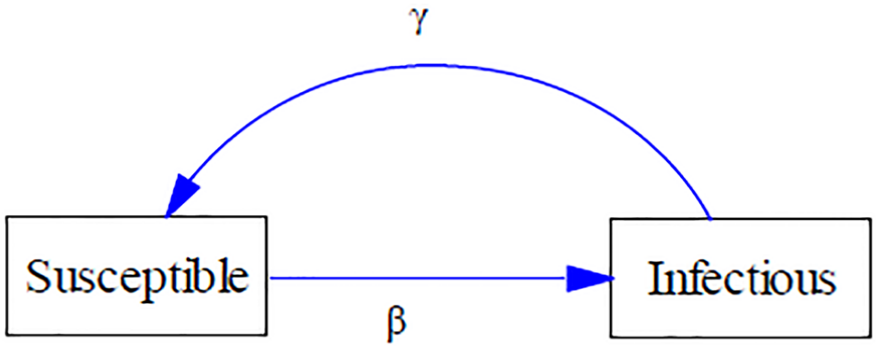
- Trachoma Amelioration in Northern Amahara (TANA) study:
  - Investigation of the impact of 1 year of **quarterly** single dose oral azithromycin treatment in children aged 1-9 on adult trachoma prevalence
  - 24 subkebeles in randomized trial with control group

	Child treatment group	Control group
Child prevalence	3.6% (95% CI: 0.8–6.4)	45.6% (95% CI: 36.7–54.5)
Adult prevalence	8.2% (95% CI: 5.1–11.4)	12.7% (95% CI: 8.9–16.6)

CSIR
our future through science

Model

- Susceptible-infected-susceptible (SIS)



- 2 age classes
  - Adults
  - Children

Parameters

Recovery

$$\gamma_c y_c = r_1$$
$$\gamma_a y_a = r_2$$

Transmission

$$(\beta_{a\to c}\frac{y_a}{N_a} + \beta_{c\to c}\frac{y_c}{N_c})x_c = r_3$$

$$(\beta_{a\to a}\frac{y_a}{N_a} + \beta_{c\to a}\frac{y_c}{N_c})x_c = r_4$$

y_a: *Infected Adults*

y_c: *Infected Children*

x_c: *Susceptible Children*

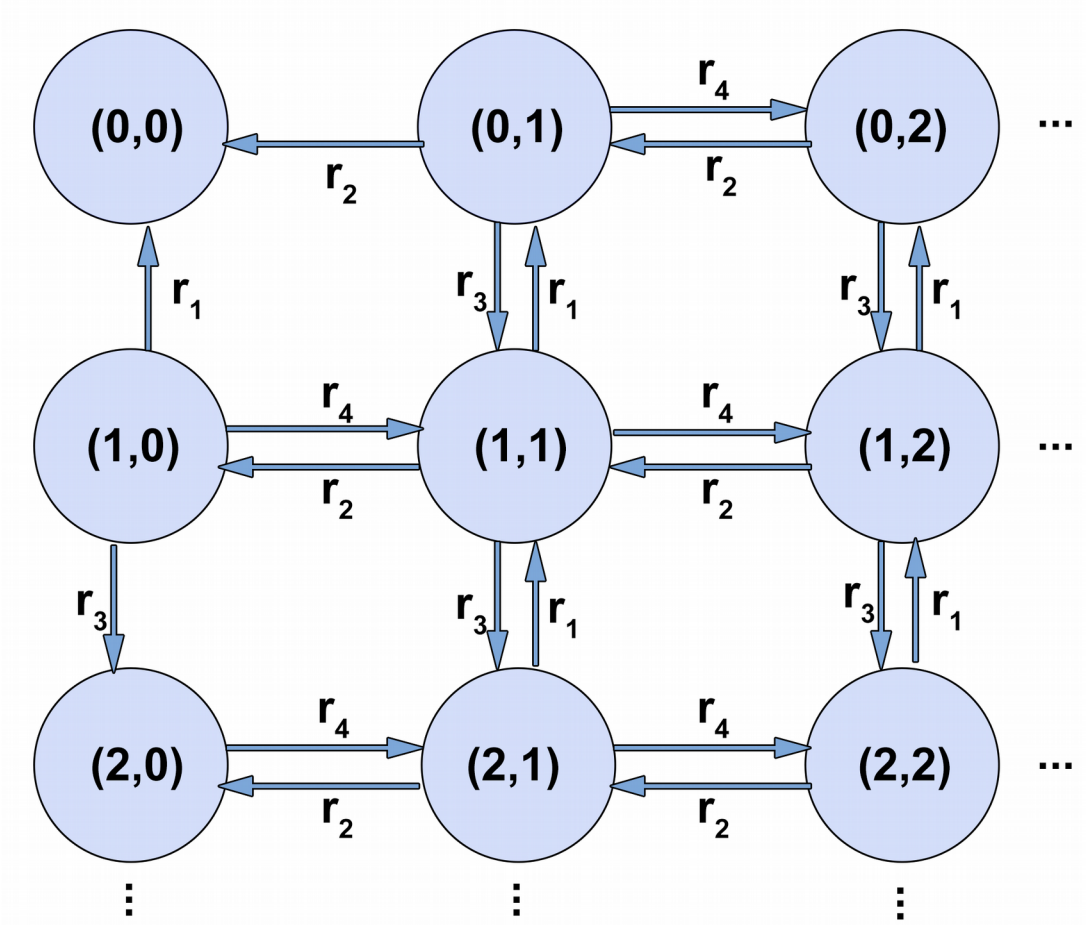
x_a: *Susceptible Adults*

N_a: *Adult Population*

N_c: *Children Population*

CSIR
our future through science

Simulation



Simulation

- Each village simulated for 100 months to allow the model to reach a state of endemic quasi-equilibrium
  - One absorbing state (epidemic extinction)

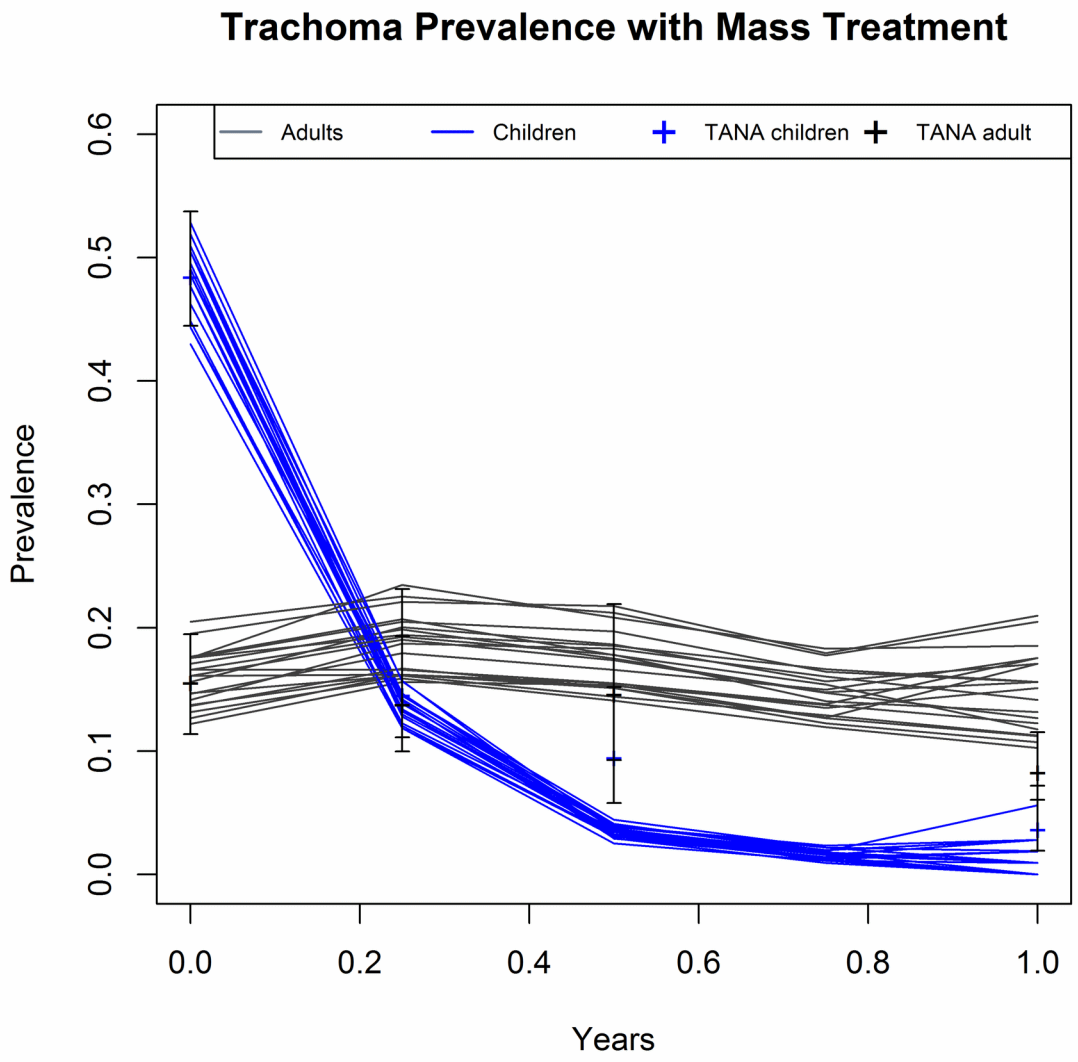
- After reaching quasi-equilibrium:
  - Simulated mass administration of azithromycin to children
  - Months 0,3,6 and 9
  - Repeated simulations averaged to derive the estimated adult and child prevalence

CSIR
our future through science

Results

Parameter	Initial Value	Final Value
Adult recovery γ_a	$\frac{0.25}{yr}$	$\frac{0.64}{yr}$
Child recovery γ_c	$\frac{0.083}{yr}$	$\frac{0.23}{yr}$
Adult $\rightarrow$ child transmission β_{ac}	$\frac{0.125}{yr}$	$\frac{0.43}{yr}$
Child $\rightarrow$ child transmission β_{cc}	$\frac{0.125}{yr}$	$\frac{0.32}{yr}$
Child $\rightarrow$ adult transmission β_{ca}	$\frac{0.0625}{yr}$	$\frac{0.34}{yr}$
Adult $\rightarrow$ adult transmission β_{aa}	$\frac{0.0625}{yr}$	$\frac{0.18}{yr}$
Odds of consecutive treatment	1	3.58
Antibiotic efficacy	0.9	0.98

Results


Trachoma Prevalence with Mass Treatment
Adults
Children
TANA children
TANA adult
Prevalence
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.0
0.2
0.4
0.6
0.8
1.0
Years

Conclusion

- Quarterly MDA campaigns administered for 10 years can greatly reduce, possibly eliminate trachoma in adults
- Transmission involving children more likely than adults
- Child recovery much slower than adults

Thank you

Questions?

[1] J.F. Martins, J.A. Oliveira-Lima, V. Delgado-Gomes, R. Lopes, D. Silva, S. Vieira, and C. Lima, ”Smart Homes and Smart buildings,” CTS/UNINOVA-DEE-FCT Univ. Nova Lisboa, Lisbon, Portugal, Electronics Conference (BEC), 2012 13th Biennial Baltic, Pages 27-38, 2012.

CSIR

our future through science