The Malaria Community Level Model.

A Decision-Making Support Tool to Formulate Effective IVM Strategies.

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Abstract

- This study proposes a simulation-based decision-making support tool to facilitate the design of effective location-specific IVM strategies. The simulation model synthesizes existing research and expert insights, and is developed by way of the System Dynamics methodology.

- (A simple and generic version of the model presented in this paper has been introduced in a previous paper “Statics and Dynamics of Malaria Transmission: The Relationship between Prevalence in Humans and Mosquitoes” also submitted for the System Dynamics conference 2020. In this sense, the present paper is a practical implementation of the generic model in order to assess the impact of malaria control interventions in a specific location)

- Preliminary calibration results in Malindi (Kenya) highlight the ability of the model to capture the major dynamics of the disease diffusion and its ability to represent IVM interventions.
Introduction

- The present study deals with a model-based decision-support tool to facilitate the design of effective location-specific IVM strategies.

- The model synthesizes existing research and expert insights, and is developed by means of the System Dynamics methodology.

- Preliminary results in endemic zones in Kenya and Ethiopia highlight the ability of the model to capture the major dynamics of the disease’s diffusion and its ability to represent IVM interventions.
Location
Location

Source: Kenya Malaria Indicator Survey 2015
Decision-Support Tool

Observation of results → Data analysis

Vector control activities ← Decision-making
Determinants of malaria transmission

ENVIRONMENTAL FACTORS

• **Climatic Factors**
  - Temperature
  - Rainfall and humidity
  - Seasonality of climate

• **Topography**
  - Altitude
  - Frost

• **Land change**
  - Weather events: hurricanes, floods and droughts
  - Stagnant water: permanent breeding sites
  - Man-made changes to the environment
SOCIO-ECONOMIC FACTORS

• Poverty
  - Malnutrition
  - Health Assistance
  - Literacy rate

• Human density
  - Urban areas
  - Migration
  - Refugee camps

• Health Control Measures
  - Prevention coverage: LLIN, IRS, EM
  - Treatment coverage: RDT, ACT’s
Determinants of malaria transmission

**BIOLOGICAL FACTORS**

- **Human Immunity level**
- **Vector and parasite densities**
  - New species
  - Behaviour
  - Predators
  - Strains resistant against insecticides or drugs
Integrated Vector Management

A rational decision-making process for the optimal use of resources for vector control

Its goal to make a significant contribution to the prevention and control of vector-borne diseases.
Malaria control interventions

- **Integrated vector management (IVM)**
  - Protective measures, e.g. ITN’s and LLIN’s
  - IRS protection.
  - Source reduction: Environmental management, Larviciding.
  - Sensitization.

- **Case Management**
  - Artemisinin-based Combination Therapies (ACTs)
  - Rapid Diagnostic Tests (RDTs)
Local Community Model

4 Sectors:

1. Outdoor mosquitoes
2. Indoor mosquitoes
3. Human population and infections
4. Interventions and cost-effectiveness
1. Outdoor mosquitoes

- Outdoor mosquitoes
- pre adult mosquitoes
- adult mosquitoes
- oviposition
- available breeding water
- source reduction interventions
- pre adult mosquitoes deaths
- maturation
- adult mosquitoes deaths
- <average temperature>
- <average humidity>
- water temperature
- larviciding interventions
- mosquitos incoming from other areas
- average temperature
- average humidity
- precipitation
- irs interventions
- llitns interventions
2. Indoor mosquitoes

- Increase in indoor density of mosquitoes
- Adult mosquito deaths

- Increase in indoor density of mosquitoes leads to:
  - More susceptible bites to humans
  - More susceptible bites to infectious humans
  - More human blood index

- Proportion of population infectious

- Mosquitoes density

- Mosquitoes activity level

- Influenza interventions

- Infectious bites to humans

- Infectious bites to infectious humans

- Infectious bites to humans leads to:
  - More infectious bites
  - More infectious bites to infectious humans
  - More mosquitoes density

- Infectious bites to infectious humans leads to:
  - More getting infectious
  - More infected mosquitoes

- Infected mosquitoes lead to:
  - More infected mosquitoes deaths
  - More infectious mosquito deaths

- Infected mosquitoes deaths
3. Human Population

Susceptible humans → Infectious bites to susceptible humans → Exposed humans → Symptoms development → Infected humans → Recovery time → Partial immune humans

Births → Susceptible humans

Susceptible natural death and emigration → Exposed natural deaths and emigration → Infected natural deaths and emigration → Partial immune natural deaths and migration

Re-exposure → Loss of immunity → Partial immunity

Average time to develop symptoms

Malaria deaths
4. Interventions

- total infected humans
- number of working months lost per month sick
- desired itn purchase
- itn unit cost
- itn purchasing
- average itn life time
- itn deterioriation
- working itn
- people covered per itn
- household sensitization
- itn coverage on bites
- proportion of mosquitoes killed by itn
- itn cost
- average monthly salary
- cumulative economic loss due to illness
- cumulative working months lost
- people covered by itn
- working months lost
Interventions Malindi

- Mass net distribution has been done in 2006, 2012 and 2015 in Malindi. In 2012 and 2015, the goal was to achieve universal coverage (1 net for 2 people) reaching 90-100% coverage.

- Sensitization campaigns are done every two weeks in Malindi. Awareness creation is related to environmental management (filling drains, etc), ITN use, and treating water bodies with larvicides.

- Larviciding started in 2006 in Malindi.

- IRS interventions have not been implemented throughout the period 2000-2015 in Malindi.
Interventions Malindi
Human Prevalence Malindi
The model developed in this paper is a useful tool for simulating the impact of alternative Integrated Vector Management strategy scenarios based on the principles of comprehensiveness, flexibility, and transparency.

Further research is geared towards applying the model in additional locations, to test its adaptability and its effectiveness for cost/effect analysis of alternative combinations of interventions.