#3963: From Risk Maps to Decision Maps for Malaria Elimination

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MALARIA RISK MAPS IN ELIMINATION SETTINGS

As recording of case surveillance data improves and large quantities of climactic, environmental and demographic data are stored in online databases, the ability to forecast risk of malaria infection on a fine geographic scale is becoming a reality.

Figure 1 demonstrates the use of hierarchical Bayesian methods to derive fine-scale risk maps from health facility-level case data (Sturrock *et al*., 2014). Predictions show broad correspondence with observed case numbers from known household locations. Fine-scale risk maps are particularly useful in elimination settings, where transmission becomes increasingly focal.

In conjunction with mathematical models, risk maps can help to advise the optimal distribution of limited resources to achieve and sustain malaria elimination. This requires an understanding of the dynamics of malaria transmission, the impact of available interventions and delivery strategies, and the financial and logistic constraints on their implementation.

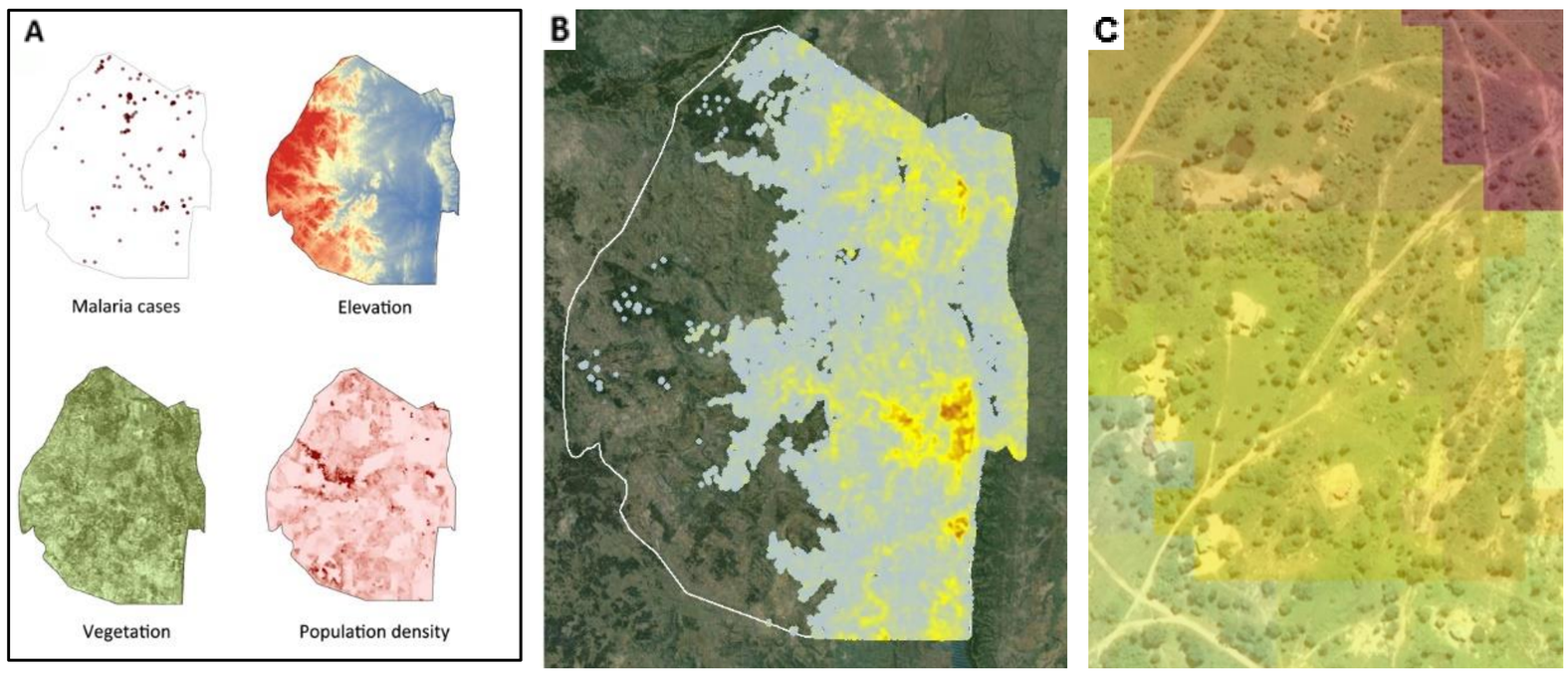

Figure 1. **(A)** Maps of health-facility level malaria case data, environmental covariates (elevation and vegetation shown here) and population density used to create fine-scale risk maps for Swaziland, shown here at the national scale **(B)** and village scale **(C)**.

WHAT WE'RE DECIDING BETWEEN

Anti-parasite interventions & delivery strategies:

In high transmission settings:	
MDA	Mass Drug Administration (all community members are treated)
MSAT	Mass Screening and Treatment (all community members are screened & treated upon detection)

In low transmission settings:	
Focal MDA	Focal Mass Drug Administration (primary cases are detected passively, household members & neighbors are presumptively treated)
RACD	Reactive Case Detection (primary cases are detected passively, household members & neighbors are then screened & treated upon detection)

Each delivery strategy has a number of options to decide between:

- **Diagnostics** (in order of increasing sensitivity): Microscopy, RDTs (Rapid Diagnostic Tests), LAMP (Loop-mediated isothermal AMPlification), PCR-based tests (Polymerase Chain Reaction)
- **Treatment:** ACTs (Artemisinin-based Combination Therapies) and/or PQ (Primaquine, or other 8-aminoquinolines)
- **Radius of testing and treatment** for focal MDA and RACD
- **Desired coverage level** for all intervention delivery strategies

Anti-vector interventions:	
LLINs	Long-Lasting Insecticide-treated Nets (tend to be distributed at the community level, main issue is compliance)
IRS	Indoor Residual Spraying with insecticides (can be performed at the community level, or performed focally, i.e. reactive spraying)
Larviciding	Performed at community level, BT toxin (*Bacillus thuringiensis*), etc.

CONSTRAINTS

Operational and financial constraints for focal intervention delivery strategies (focal MDA and RACD) are currently being quantified from observational studies and clinical trials.

Types of constraints:	
Technical	Inherent in the mathematical modeling framework, describe limitations of currently-available tools to reduce transmission
Operational	Defied by logistical considerations (e.g. human resources, transport, ability of national organizations to carry out the program)
Financial	Defined by program costs and funds available over a sustained period

Determining optimal interventions and delivery strategies is then a constrained optimization problem in which a desired outcome (e.g. clinical incidence) is minimized by exploring the above parameters subject to operational and financial constraints.

MATHEMATICAL MODELS

Figure 2 depicts sample output from an individual-based model, based on the malaria transmission model of Griffin *et al.* (2010), reproduced in panel A. Here,

- Force of infection (probability of infection per person per unit time) varies with age, individual attractiveness to mosquitoes, and geographical heterogeneity in risk. Risk maps can be used to determine geographical heterogeneity.
- Malaria infections can be symptomatic (red), asymptomatic and detectable by microscopy (orange), or asymptomatic and detectable by PCR (yellow).

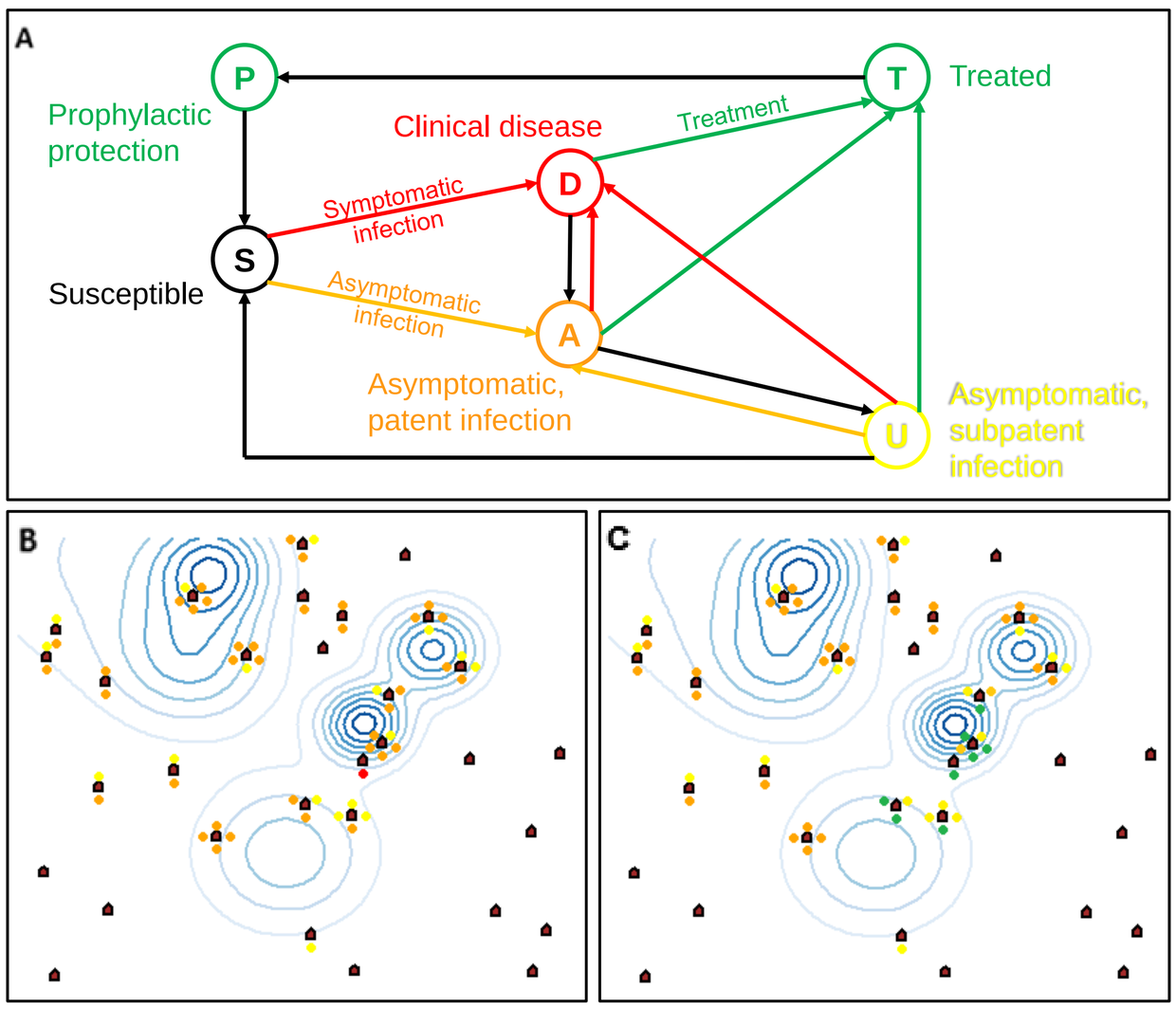

Figure 2. **(A)** Malaria transmission model. Individuals can become clinically infected (red arrows), asymptomatically infected (orange arrows) and treated (green arrows). Individuals are defined according to infection status, which is color-coded. This color scheme is adopted in the simulation output in panels B and C. **(B)** Brown pentagons represent households, blue isoclines represent spatial risk (fading with distance from breeding sites at the center of each set of isoclines). Colored dots represent infected or treated individuals living in these households. In low prevalence areas, most infections are asymptomatic and clustered in high risk areas. Upon clinical infection (the red dot in panel B), there is a probability that this case will be presented to a local medical center. **(C)** In panel C, this triggers RACD, which results in a fraction of nearby asymptomatic, patent (orange) cases testing positive and being treated (becoming green).

REFERENCES

Sturrock *et al.* (2014) Fine-scale malaria risk mapping from routine aggregated case data. Malar J **13**: 421.

Griffin *et al.* (2010) Reducing *Plasmodium falciparum* malaria transmission in Africa: A model-based evaluation of intervention strategies. PLoS Med **7**: e1000324.