The International Research Institute for Climate and Society

Pontificia Universidad JAVERIANA Bogotá

Public Health, Climate and Infectious Diseases Interactions

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Workshop on Mathematical Models of Climate Variability, Environmental Change and Infectious Diseases

Outline

- Conceptual frameworks
- Public Health Approach
- Public Health and Climate interactions

Setting the scene*

F1: Medical

"individual, patient-based model": germ theory

Research goal : to develop a drug or a vaccine

Clinical Trial

F2: Epidemiological

" population based model" : Incidence, Prevalence, # cases are f(Host Pathogens / Risk Factors).

Research goal. To understand the web causality - complex inter-relationship of numerous direct and indirect factors that interact to alter the risk of disease − in space and time

Risk factor analysis (statistical models)

F3: Ecological

"host–pathogen interactions model" : biology and evolutionary ecology principles.

Research goal : to examine patterns of ID occurrence as a product of biological processes (contact rate ,transmissibility…)

Mathematical models (Differential Equations) : SIR, SEIR models

*Smith, K, et al, (2005), Ecological theory to enhance infectious disease control and public health policy, Front Ecol Environ 3(1): 29–37

Getting back to F3: last week wrap up

Some of the challenges:

(i) how to introduce extrinsic and intrinsic factors to diseases dynamics .(???)

(ii) how to match/test epi-data with those mathematical models using statistical/ simulation models. Issues: estimation initial conditions; stochastic behavior { noise treatment};, parameters uncertainties {literature, pdf, likelihood} (????);

(iii) How to get a good balance between model complexity and model usefulness. (???)

(iv) how to use those models to improve/ help the decision making process of public health officers. (??????)

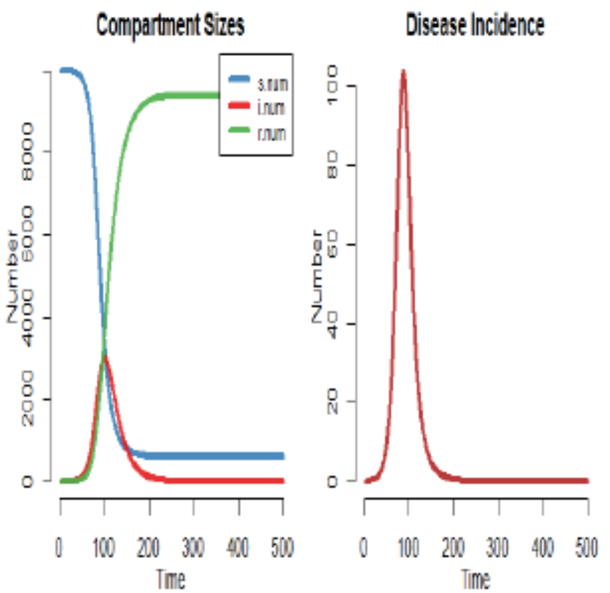


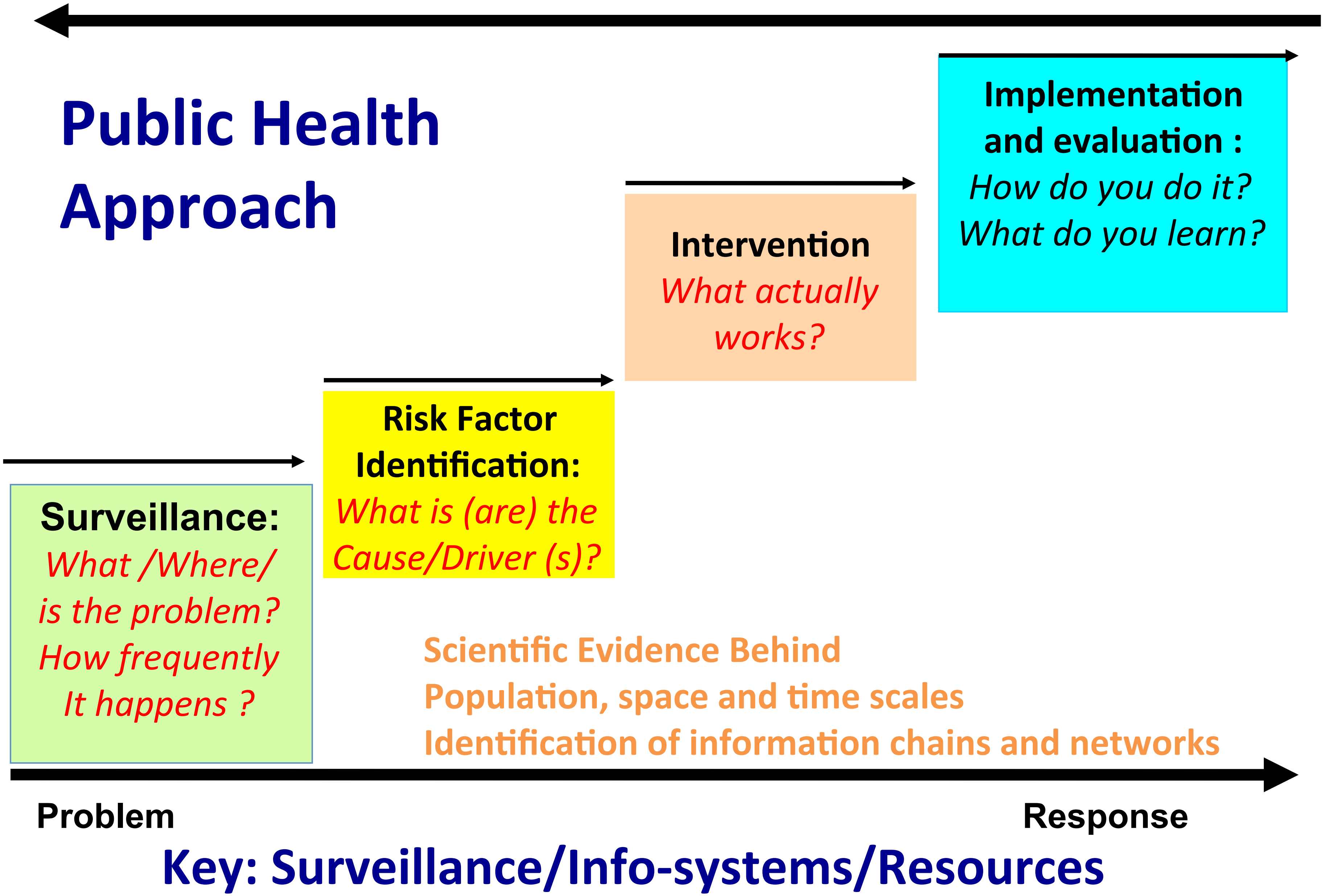
Figure 6 : SIR - (r-lib: Epimodel)

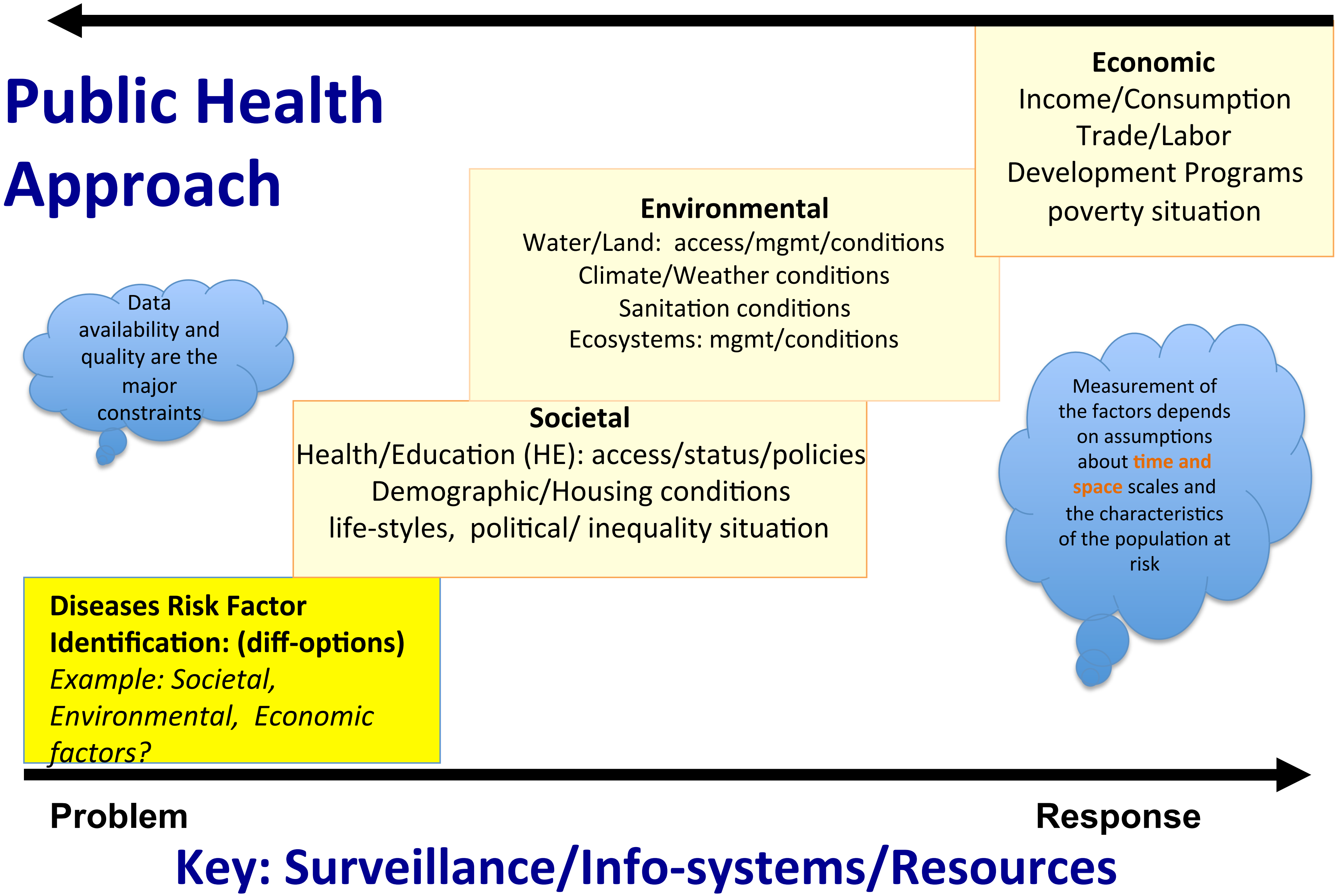
Public Health: the scope

Public Health is what we, as a society, do collectively to protect, promote and restore the people's health

"the art and science of preventing disease, prolonging life and promoting health through the organized efforts of society" (Acheson, 1988; WHO).

"public health was founded on the principle of social justice as a basic right" APHA.


Public Health Approach
Implementation and evaluation :
How do you do it?
What do you learn?
Intervention
What actually works?
Risk Factor Identification:
What is (are) the Cause/Driver (s)?
Surveillance:
What /Where/ is the problem?
How frequently It happens ?
Scientific Evidence Behind
Population, space and time scales
Identification of information chains and networks
Problem
Response
Key: Surveillance/Info-systems/Resources



Public Health Approach
Economic
Income/Consumption
Trade/Labor
Development Programs
poverty situation
Environmental
Water/Land: access/mgmt/conditions
Climate/Weather conditions
Sanitation conditions
Ecosystems: mgmt/conditions
Data availability and quality are the major constraints
Societal
Health/Education (HE): access/status/policies
Demographic/Housing conditions
life-styles, political/ inequality situation
Measurement of the factors depends on assumptions about time and space scales and the characteristics of the population at risk
Diseases Risk Factor Identification: (diff-options)
Example: Societal, Environmental, Economic factors?
Problem
Response
Key: Surveillance/Info-systems/Resources

Questions

- How much disease is caused by a particular risk factor (the attributable burden of disease)?
- How much could be avoided by making plausible reduction in the risk factor (the avoidable burden of disease)?
- Why do certain people develop disease (or experience an adverse health outcome) when challenged with harmful environmental exposures, while others remain healthy?
- Should we intervene?
- Where should we intervene?
- How much intervention is required?
- What are the costs? Can we afford it?
- How frequently?
- What tools should we use for monitoring progress?
- How will we measure the success of the program?

Climate and Public Health:

a very old and renovated relationship

Hippocrates, Father of Medicine
Born in 460 B.C. - Died in 377 B.C.
"Airs, Waters, Places".

ΠΕΡΙ ΑΕΡΩΝ ΥΔΑΤΩΝ ΤΟΠΩΝ

Ἰητρικὴν ὅστις βούλεται ὀρθῶς ζητεῖν, τάδε χρὴ ποιεῖν· πρῶτον μὲν ἐνθυμεῖσθαι τὰς ὥρας τοῦ ἔτεος, ὅ τι δύναται ἀπεργάζεσθαι ἑκάστη· οὐ γὰρ ἐοίκασιν ἀλλήλοισιν οὐδέν, ἀλλὰ πολὺ διαφέρουσιν αὐταί τε ἐφ᾽ ἑωυτέων καὶ ἐν τῇσι μεταβολῇσιν· ἔπειτα δὲ τὰ πνεύματα τὰ θερμά τε καὶ τὰ ψυχρά, μάλιστα μὲν τὰ κοινὰ πᾶσιν ἀνθρώποισιν, ἔπειτα δὲ καὶ τὰ ἐν ἑκάστη χώρη ἐπιχώρια ἐόντα. δεῖ δὲ καὶ τῶν ὑδάτων ἐνθυμεῖσθαι τὰς δυνάμιας …

Hippocrates, c. 400 BC

Whoever wishes to pursue properly the science of medicine must proceed thus: first he ought to consider what effects each season of the year can produce – for the seasons are not all alike, but differ widely both in themselves and at their transitions; the next point is the hot winds and the cold, especially those that are universal, but also those that are peculiar to each particular region; and he must also consider the properties of the water …

Dr. Margaret Chan
Director-General WHO
Message Celebrating World Health Day, 2008

"Climate change will affect, in profoundly adverse ways, some of the most fundamental determinants of health: food, air, water."

Climate and Public Health:

a very old and “stable” relationship

Hippocrates, Father of Medicine
Born in 460 B.C. - Died in 377 B.C.
“Airs, Waters Places".

ΠΕΡΙ ΑΕΡΩΝ ΥΔΑΤΩΝ ΤΟΠΩΝ

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EPA USA
Climate Impacts on Human Health
Key Points

“Climate change can affect human health in two main ways: first, by changing the severity or frequency of health problems that are already affected by climate or weather factors; and second, by creating unprecedented or unanticipated health problems or health threats in places or times of the year where they have not previously occurred.”

https://www.epa.gov/climate-impacts/climate-impacts-human-health (April 28 -2017)

Public Health and Climate: the menu

Public Health: strategies

Primary: to prevent the onset of injuries or illness.

Examples-> , immunization, safe water, campaigns of: safe sex, clean water/air, anti-smoking, safe car-bicycle practices, bed nets….

Secondary: to diagnose disease early to control/prevent its progress and diminish the resulting health burden;

Examples-> screening/testing for: malaria, diabetes, cancer, hypertension, hyperlipidemia…

Tertiary: to elude complications, and restore functions in order to decrease/ prevent morbidity and mortality.

Examples-> using specialized-scientific driven short/medium/long term treatments: chemotherapy

Climate: strategies

Mitigation: "A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs)", (IPCC).

Examples-> promoting/providing: afforestation, clean energy sources/uses at all levels; public transport for communities.

Adaptation: "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities", (IPCC).

Examples-> promoting/providing proper/tailor made interventions at all levels under expected/ observed weather/climate events

Examples of climate sensitive Communicable Diseases (CD)

Vector-borne

Malaria *
Dengue Fever ,
Zika*, Chikungunya *
Lyme disease @
West Nile (R,T)
Rift Valley fever (R, CV[ENSO])
Hantavirus pulmonary syndrome &
Leishmaniosis, (T, CV[ENSO])
African trypanosomiasis (T)
Tularemia (*)
Plague (&)
Onchoceriasis (river blindness) (T)

Water and Foodborne

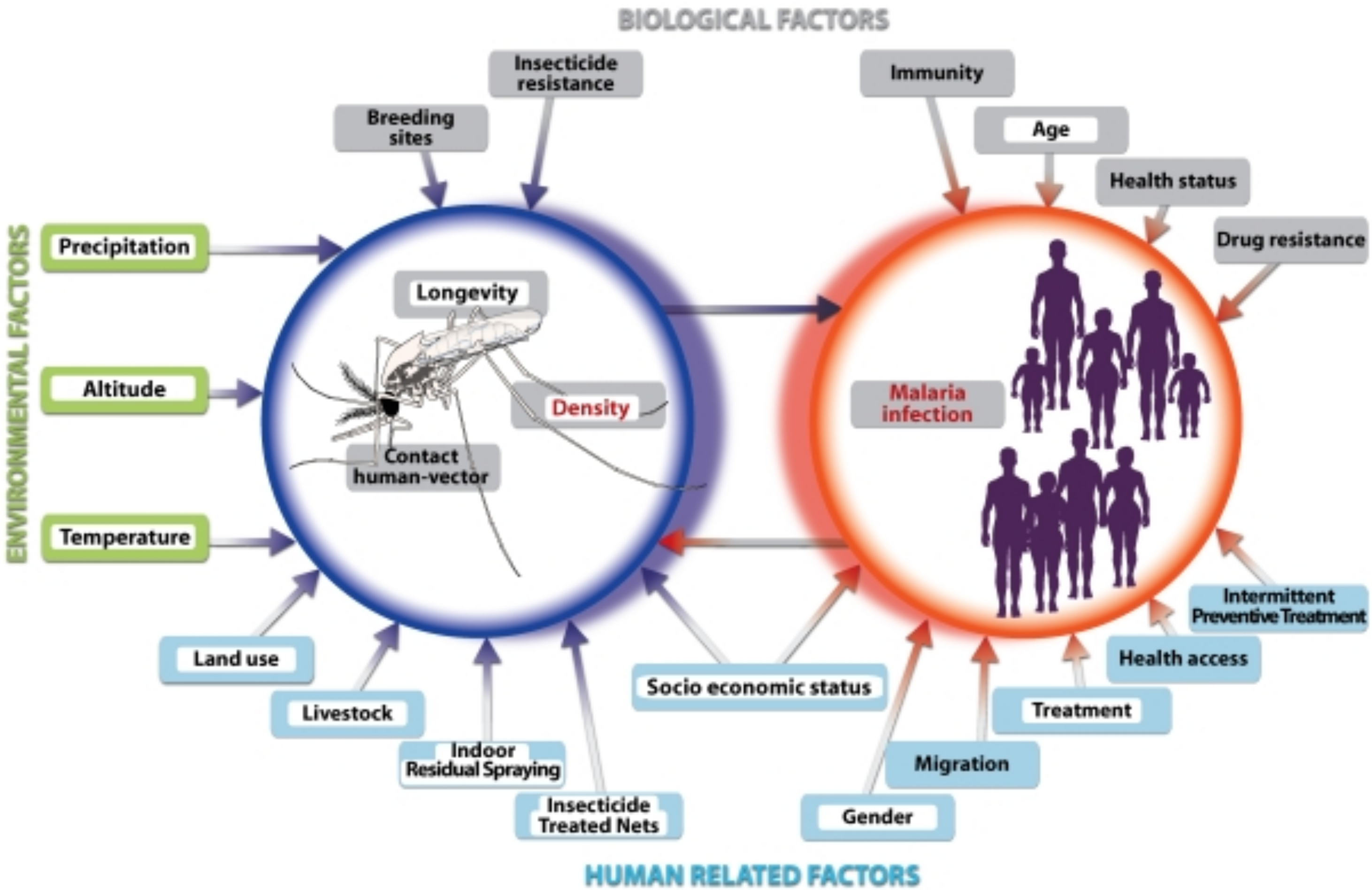
Cholera &
Leptospirosis &
Schistosomiasis (T,R)
Giardiasis &
Cryptosporidiosis &
Human enteric viruses (Enteroviruses,. Norwalk and Norwalk-like viruses) (T)
Campylobacteriosis &
Salmonella enteritidis (T,D)

Airborne (and others)

Meningococcal Meningitis (H,S,W)
Coccidioidomycosis (D,P,T,W)
Respiratory syncytial virus (Coldwaves ,(S,T)
Influenza (T,H)

Climate and Extreme weather/climate conditions: (R)ain, (T)emperature, (H)umiditity, (W)Winds, (F)looding, (D)rought, (ET) Heatwaves/ColdWaves, (S)easonal * (R,T,H), &(R,F) ^(ET,H,R), @(T,R,S), (CV) climate variability

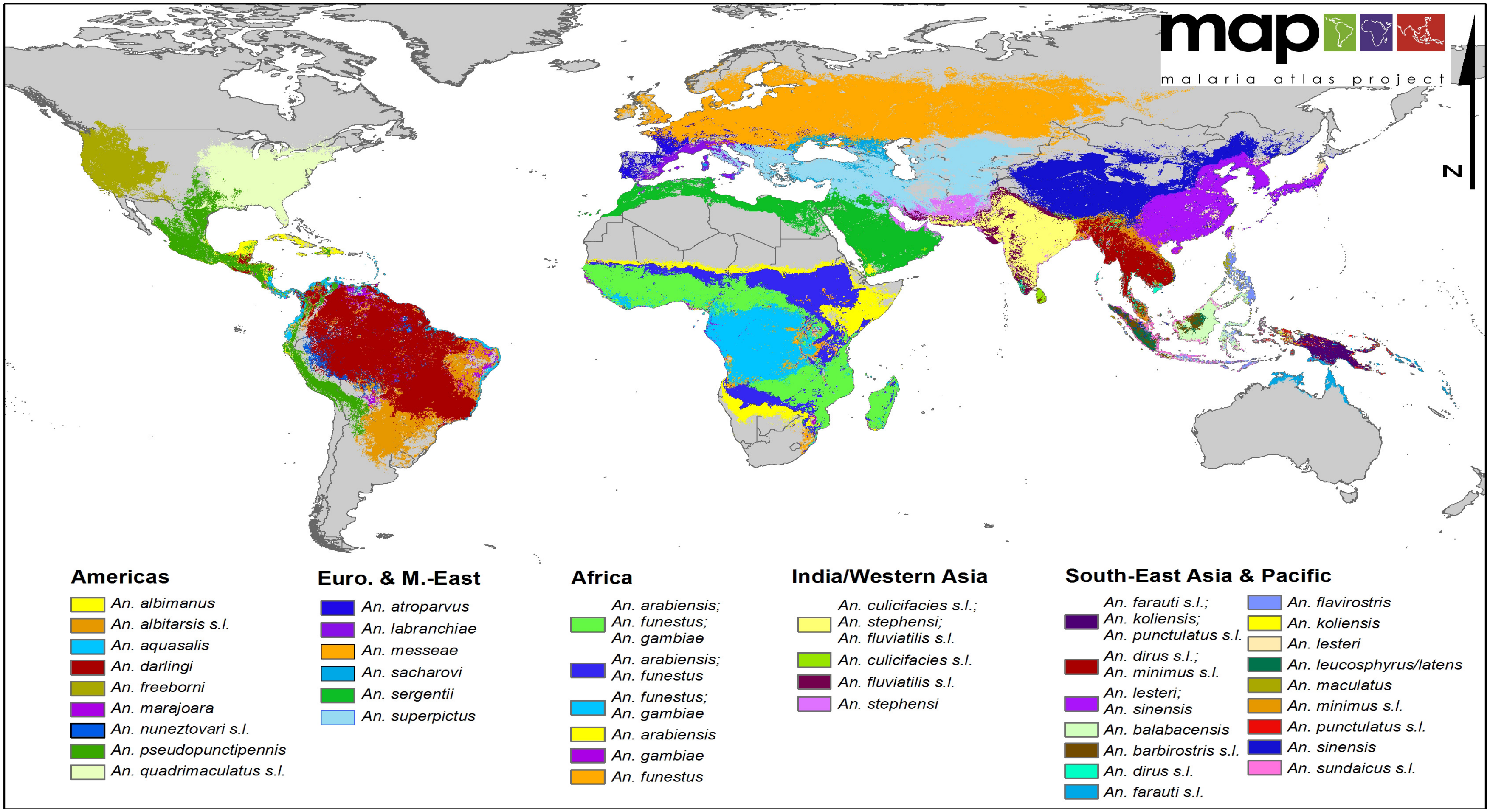
Public Health Approach:
Malaria risk factors



Source: Protopopoff, N., et al. (2009), Ranking Malaria Risk Factors to Guide Malaria Control Efforts in African Highlands, PLoS ONE 4(11): e8022. doi:10.1371/journal.pone.0008022

Public Health Approach

Another malaria glimpse:
Global vector distribution: published 2012



Sinka, M., et al. (2012), Parasites & Vectors 2012, 5:69

Public Health Approach

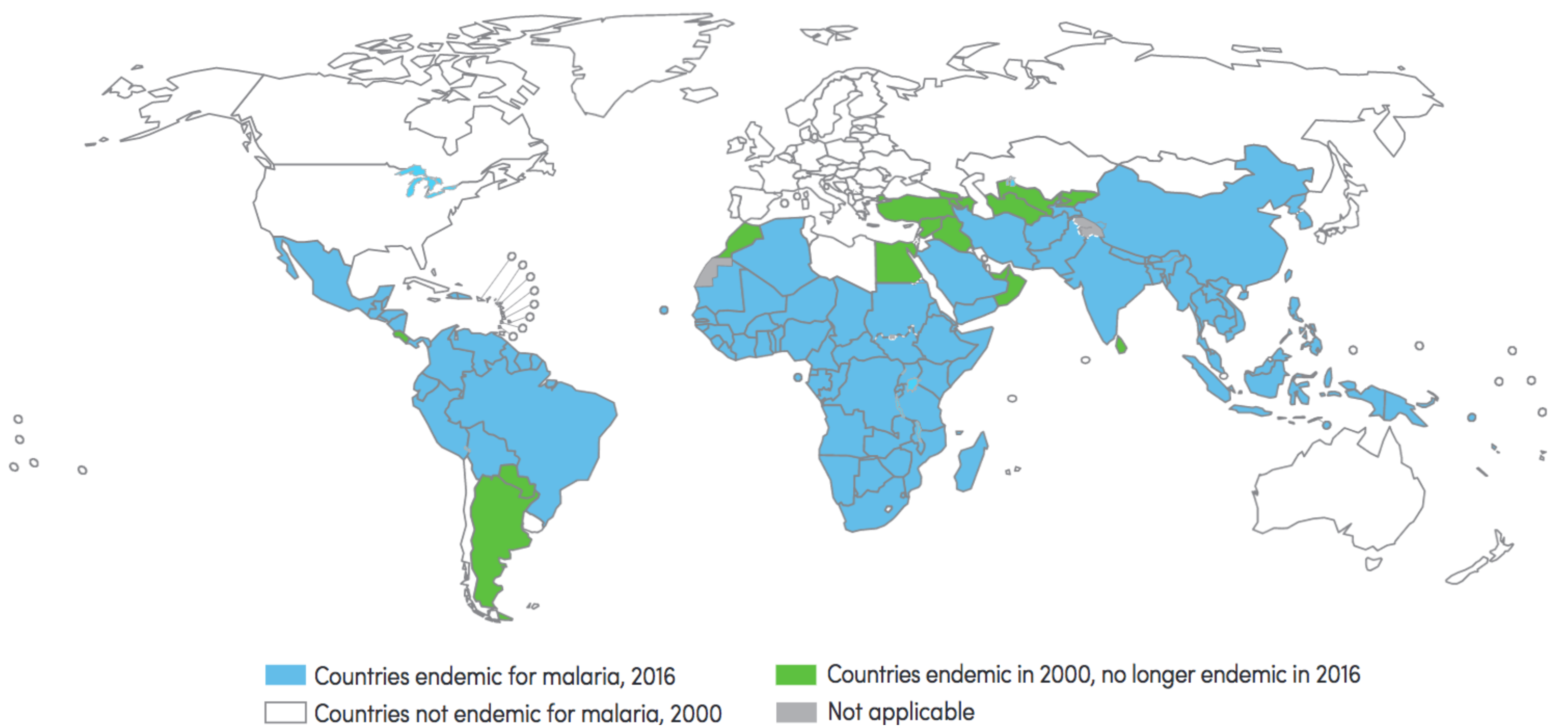
Another malaria glimpse:

Global endemic distribution: 2016 geo-unit: country

At the start of 2016, nearly half of the world's population was at risk of malaria.

Malaria was considered to be endemic in 91 countries and territories in 2016, down from 108 in 2000. Most of the change can be attributed to the wide-scale deployment of malaria control interventions.

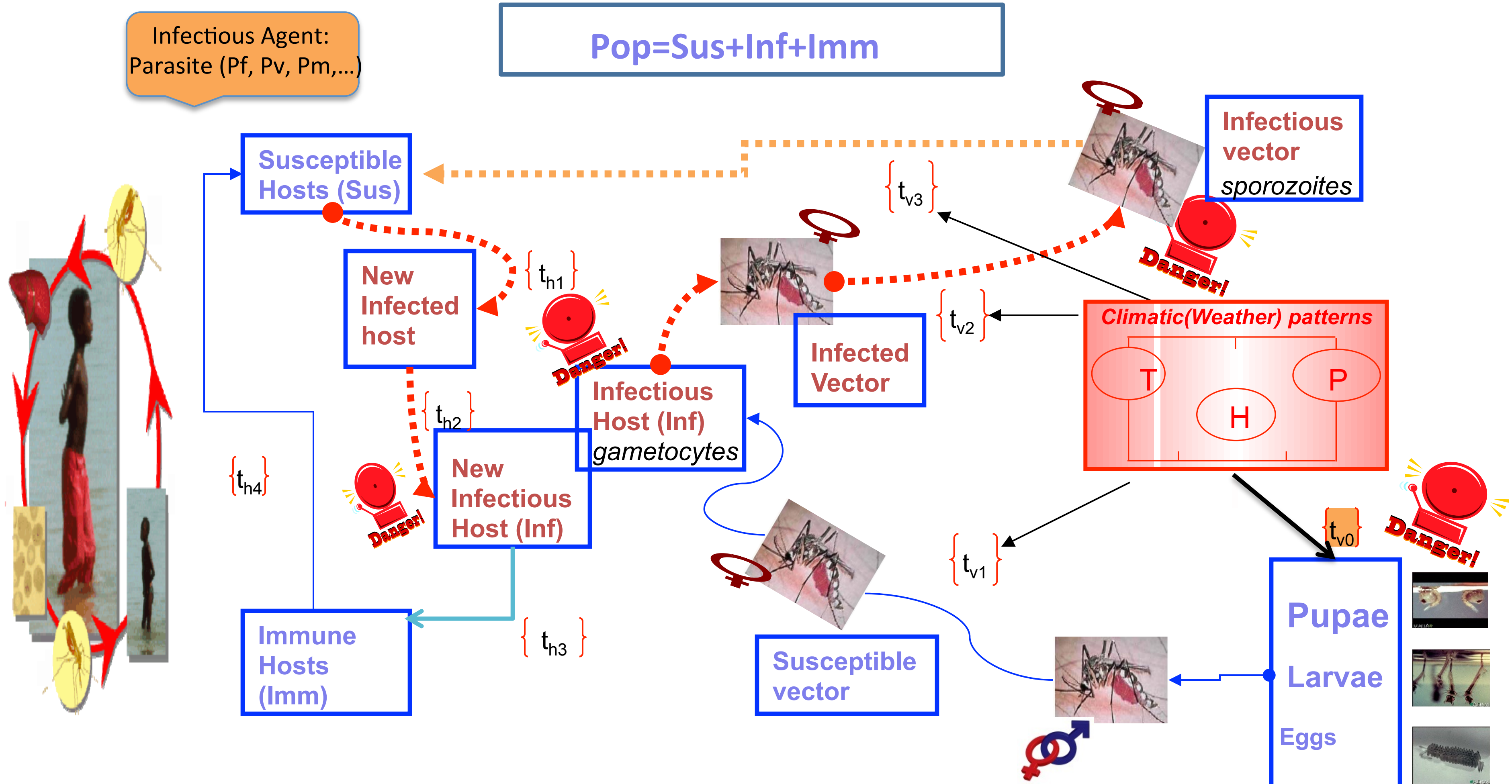
Countries endemic for malaria in 2000 and 2016



WHO, Malaria World Report 2016

Public Health Approach

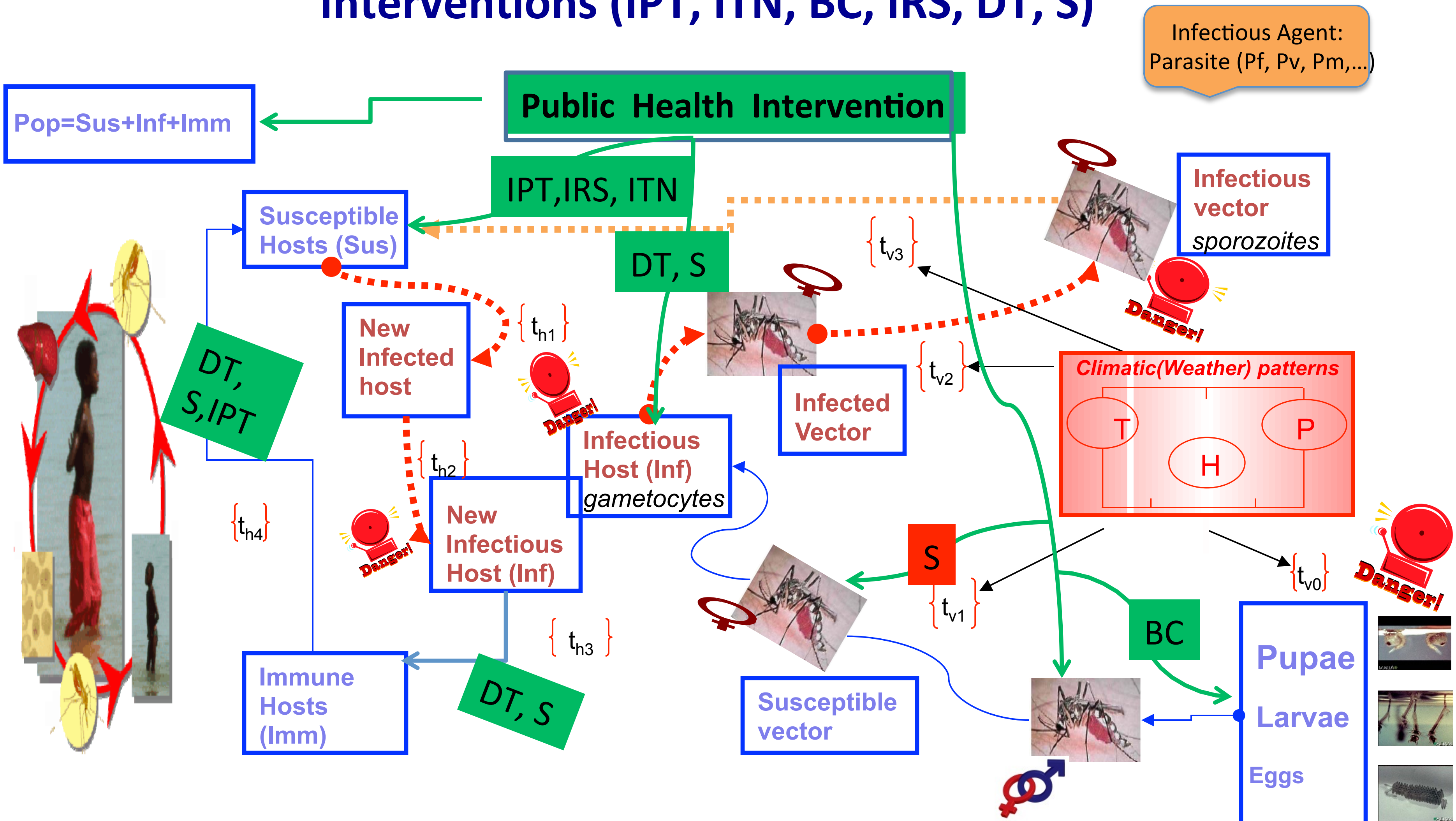
Malaria Transmission Mechanism (MTM)



See for instance: Ruiz, D., et al. *Modelling entomological-climatic interactions of Plasmodium Falciparum malaria transmission in two Colombian endemic-regions: contributions to a National Malaria Early Warning System.* Malaria Journal, 2006, 5:66.

Public Health and Malaria

Interventions (IPT, ITN, BC, IRS, DT, S)



See for instance: Ruiz, D., et al. *Modelling entomological-climatic interactions of Plasmodium Falciparum malaria transmission in two Colombian endemic-regions: contributions to a National Malaria Early Warning System.* Malaria Journal, 2006, 5:66.

Public Health and Malaria Interventions (ITN, BC, IRS, DT, S)

Individual Annual cost

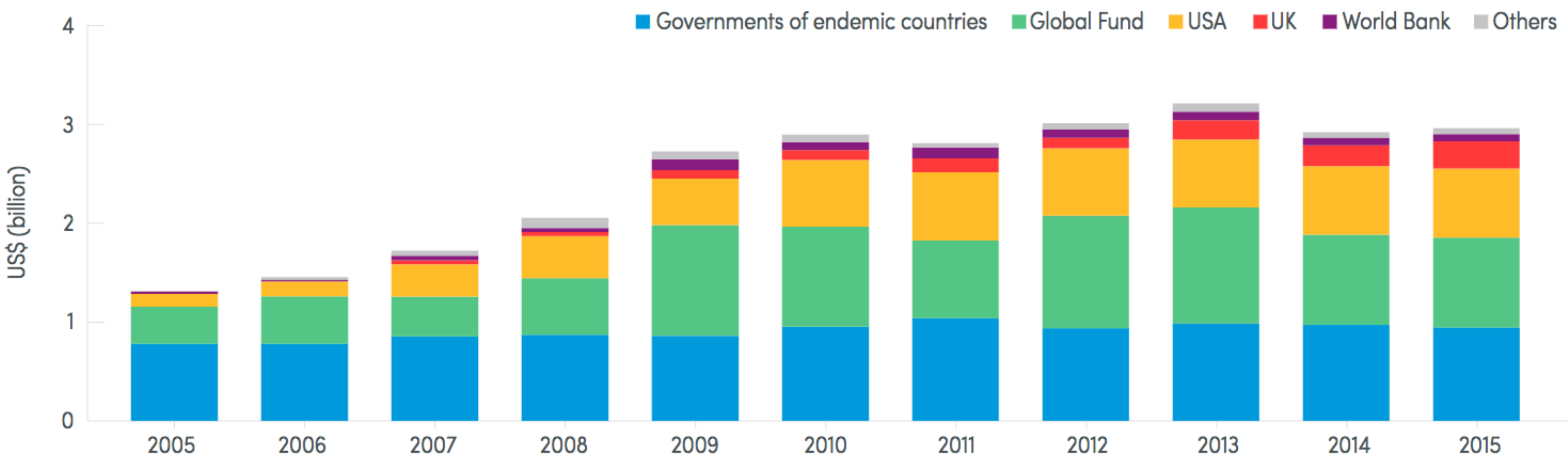
Intevention	Cost (U$)	Cost Prevention (U$)
ITN	2.2	
IRS	6.7	
IPT		
Infants	0.6	9.5
Under 5 years	4.03	12.93
Pregnant women	2.06	10.96
Dx	4.32	
Treatment		
Uncomplicated	5.84	
Severe malaria	30.26	

Source: White et al . Malaria Journal 2011, 10 :337

Public Health Approach

Another malaria glimpse:
Malaria control activities by founding source

Investments in malaria control activities by funding source, 2005–2015



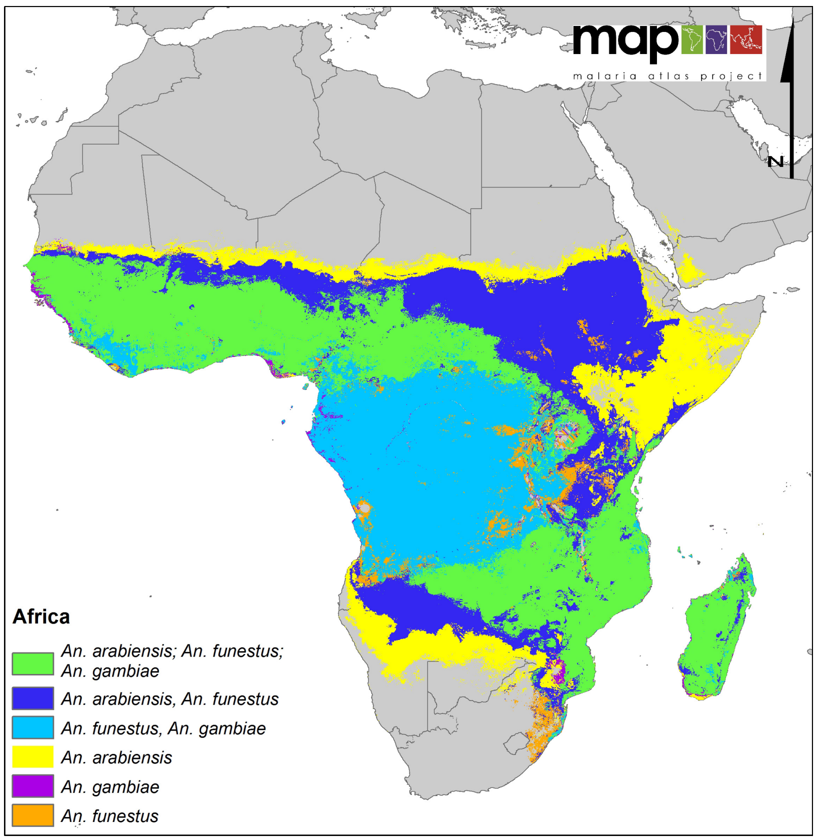
Global Fund, Global Fund to Fight AIDS, Tuberculosis and Malaria; UK, United Kingdom of Great Britain and Northern Ireland; USA, United States of America
Annual values have been converted to constant 2015 US$ using the gross domestic product implicit price deflator from the USA in order to measure funding trends in real terms.

Sources: *ForeignAssistance.gov, Global Fund to Fight AIDS, Tuberculosis and Malaria, national malaria control programme reports, Organisation for Economic Co-operation and Development (OECD) creditor reporting system, the World Bank Data Bank, WHO estimates of malaria cases and treatment seeking at public facilities, and WHO CHOICE unit cost estimates of outpatient visit and inpatient admission*

Public Health Approach

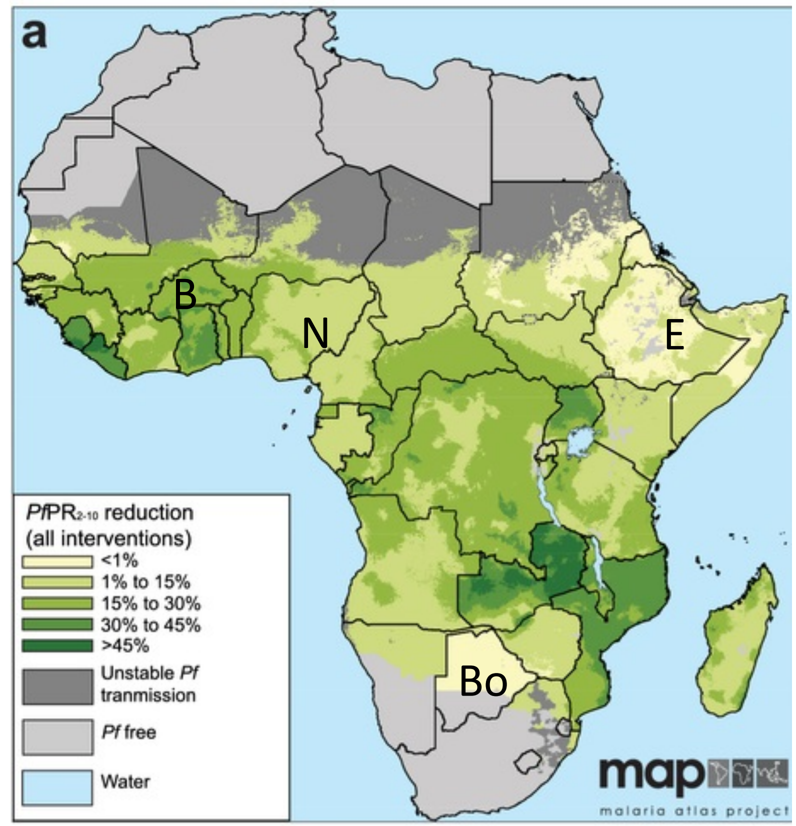
Another malaria glimpse:
Africa situation

Vector Distribution: published 2012



Sinka, M., et al. (2012), Parasites & Vectors 5:69

Evolution PfPR_2-10 (2015/2000)



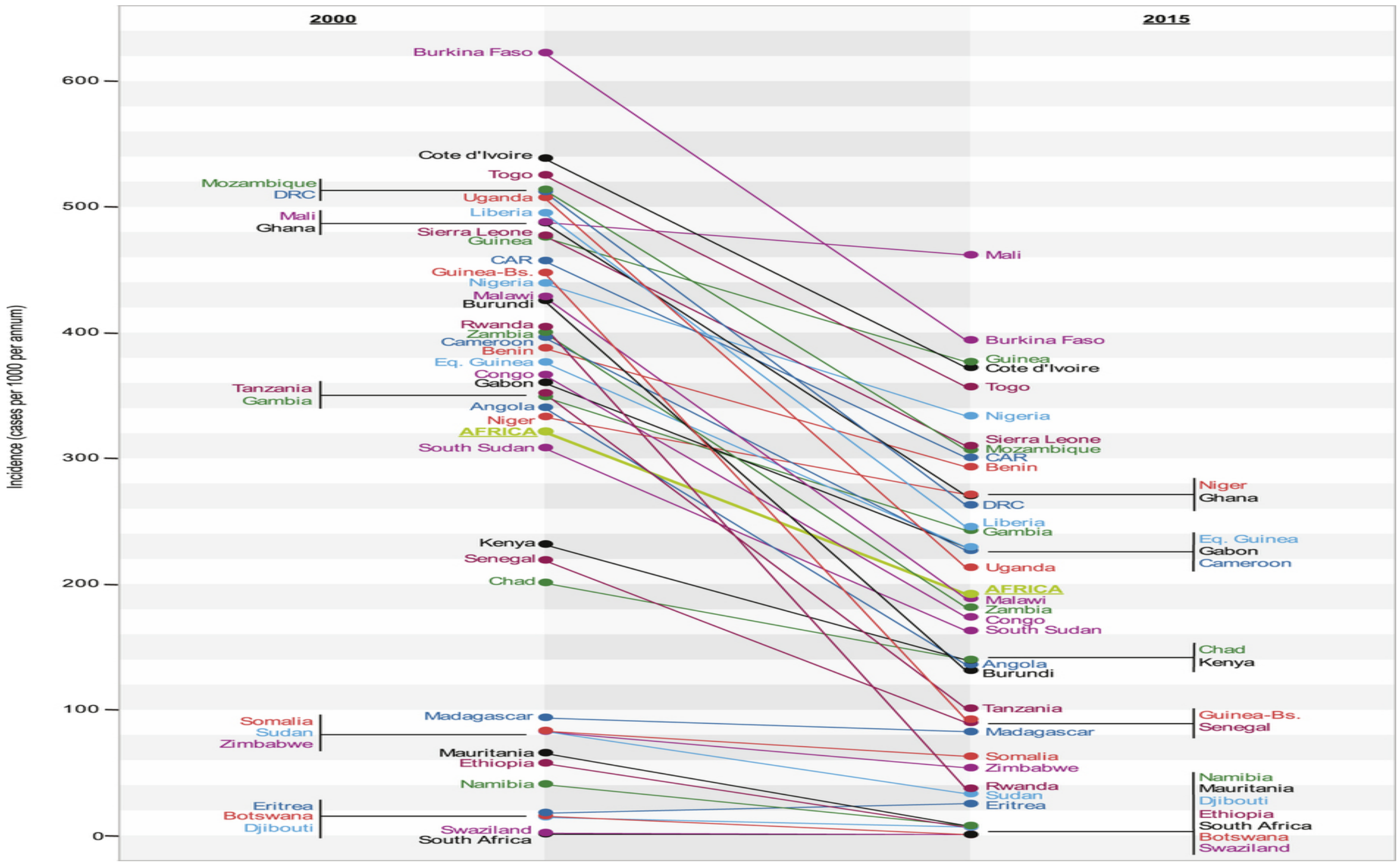
Bhatt, S., et al. (2015), Nature 526, 207–211 doi:10.1038/nature15535

Public Health Approach

Another malaria glimpse:

Africa situation

Country Incidence rate evolution: (# cases by 1000 per annum) after interventions



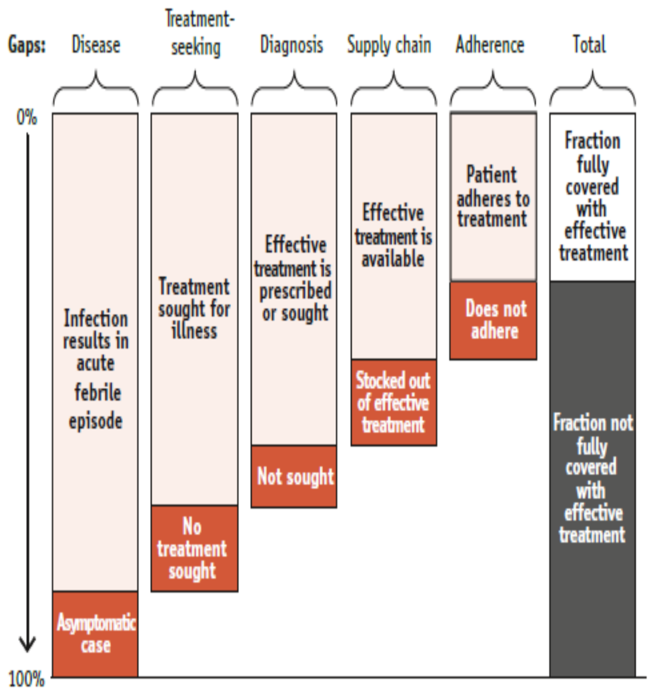
Bhatt, S., et al. (2015), Nature 526, 207–211 doi:10.1038/nature15535

Public Health Approach

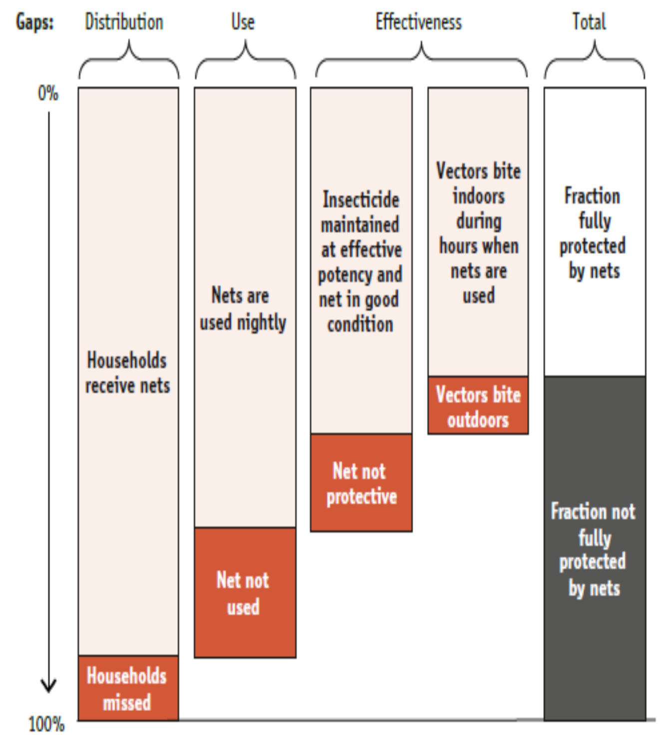
Another malaria glimpse:

Issues regarding surveillance and interventions

Potential coverage gaps that determine the fraction of infections rapidly identified and treated.



Hypothetical illustration of some potential coverage gaps that determine the fraction of the population fully protected by nets.

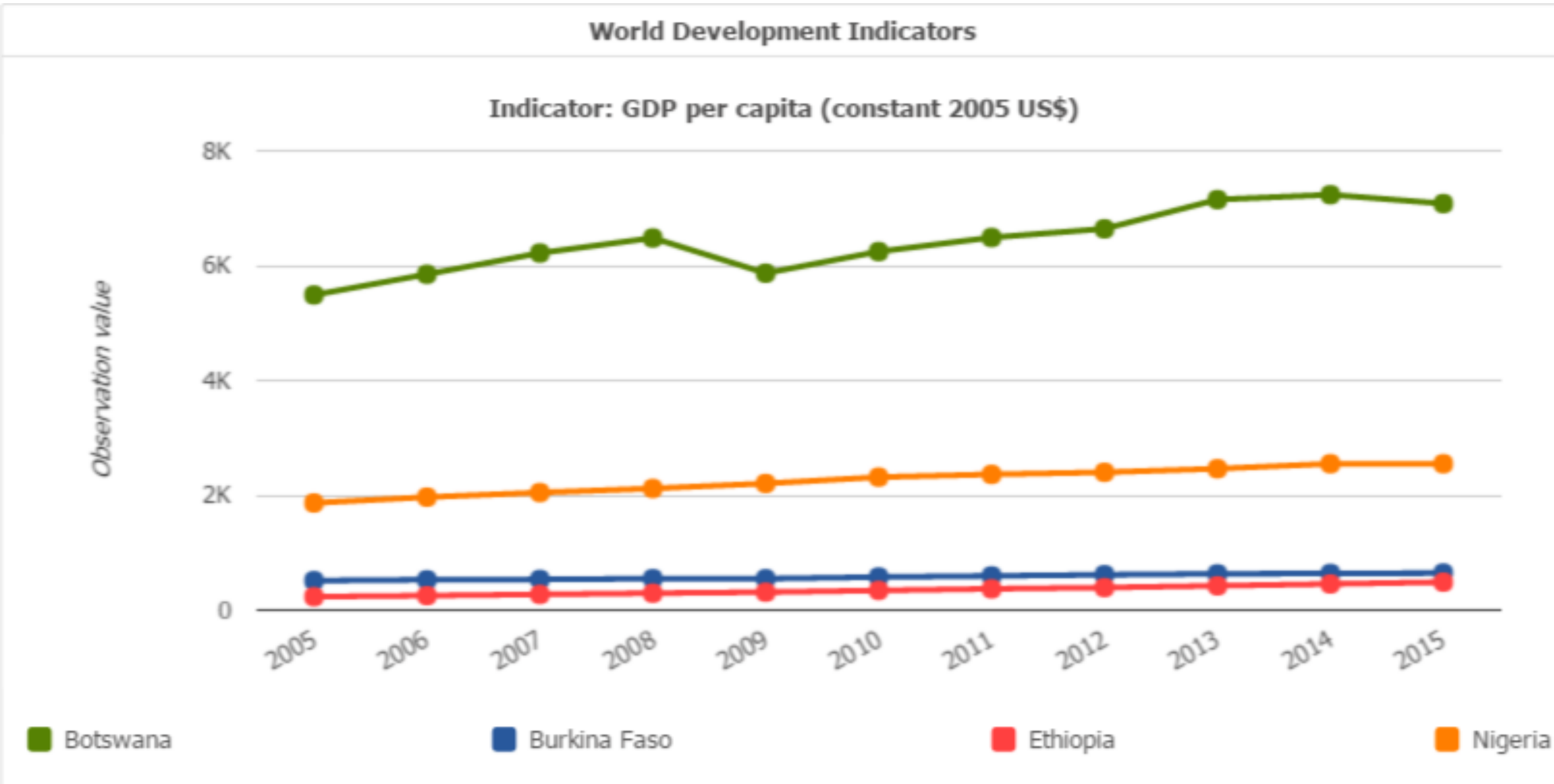


WHO, (2014), From Malaria Control to Malaria elimination: A manual for elimination scenario planning, WHO.

Public Health Approach

Another malaria glimpse:

Evolution some indicators associated with risk factors



Public Health Approach

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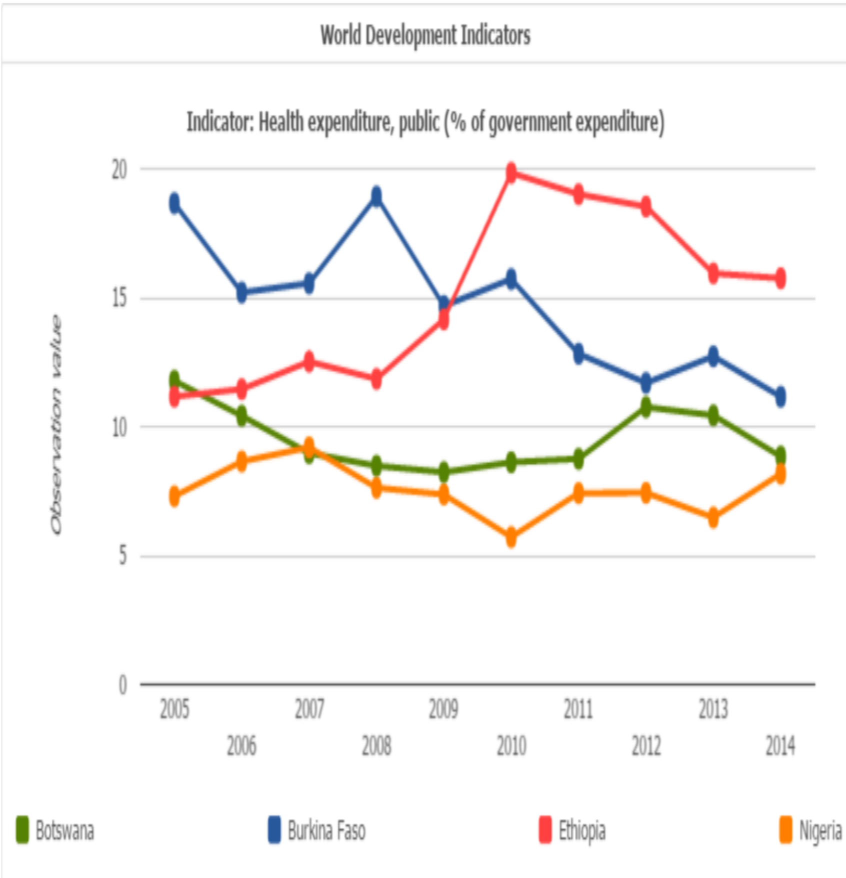
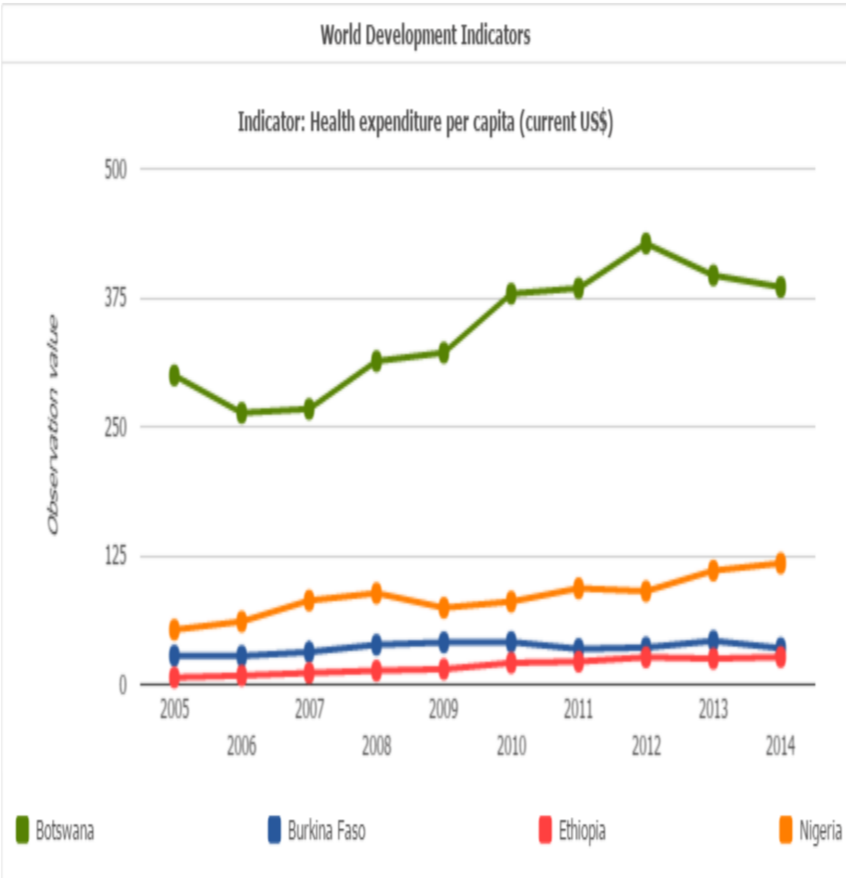
Evolution some indicators associated with risk factors



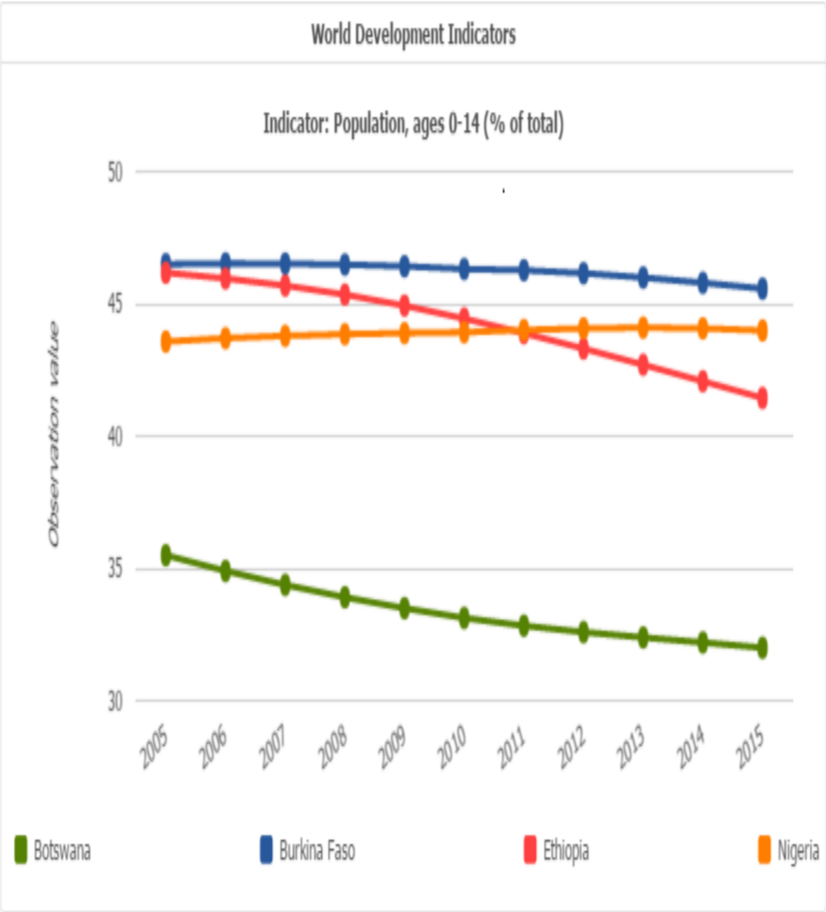


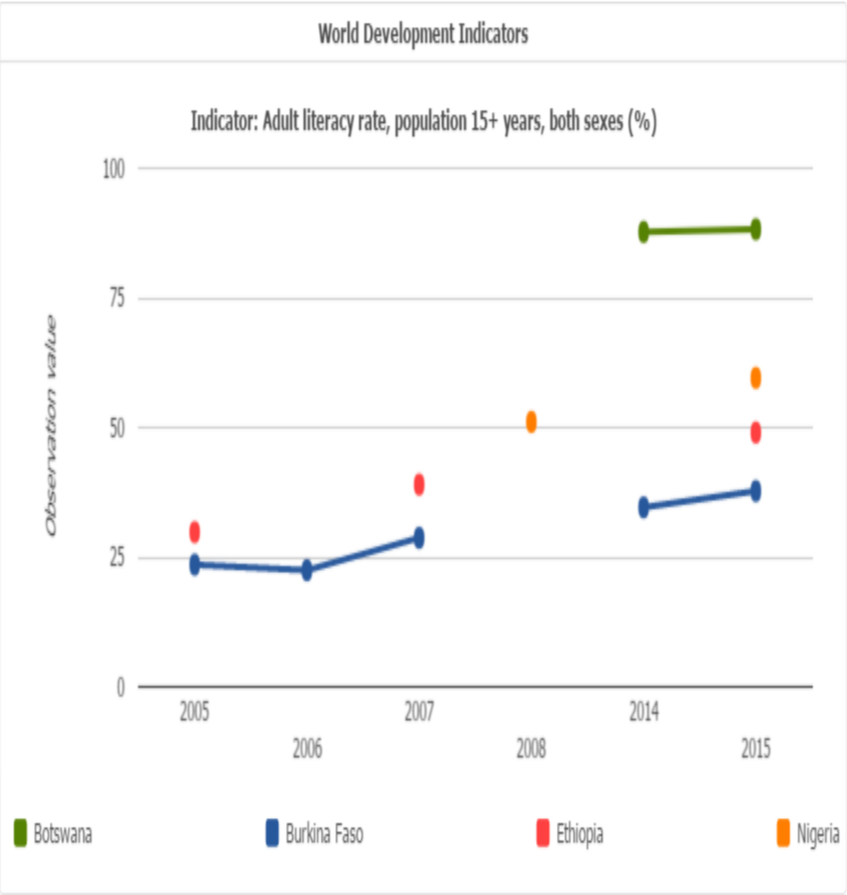
World Bank, Development Indicators

Public Health Approach

Another malaria glimpse:

Evolution some indicators associated with risk factors



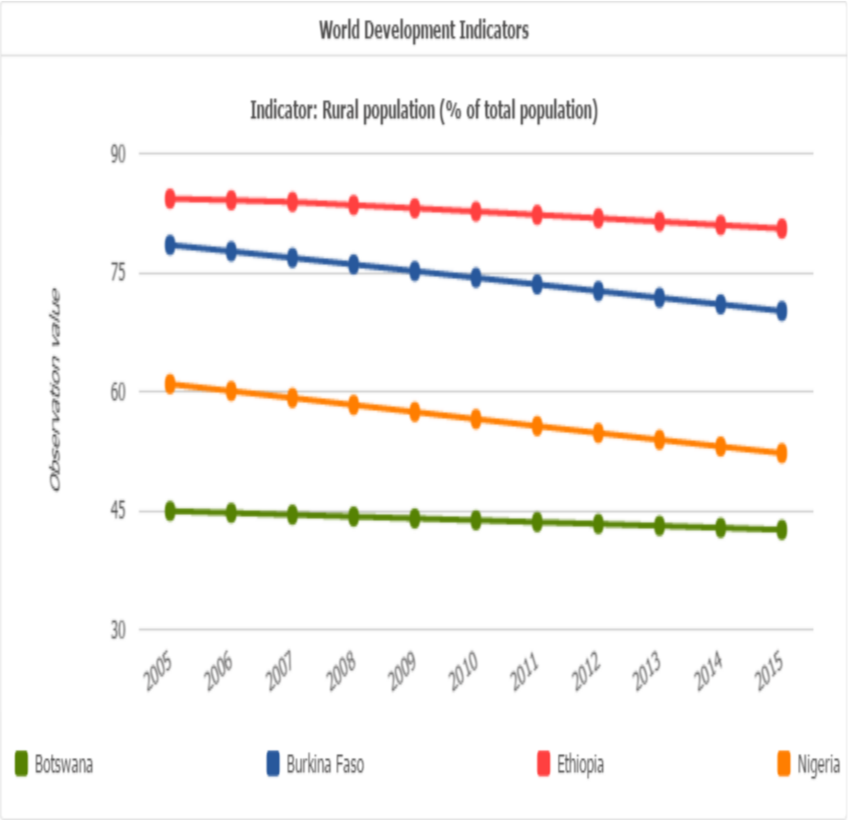


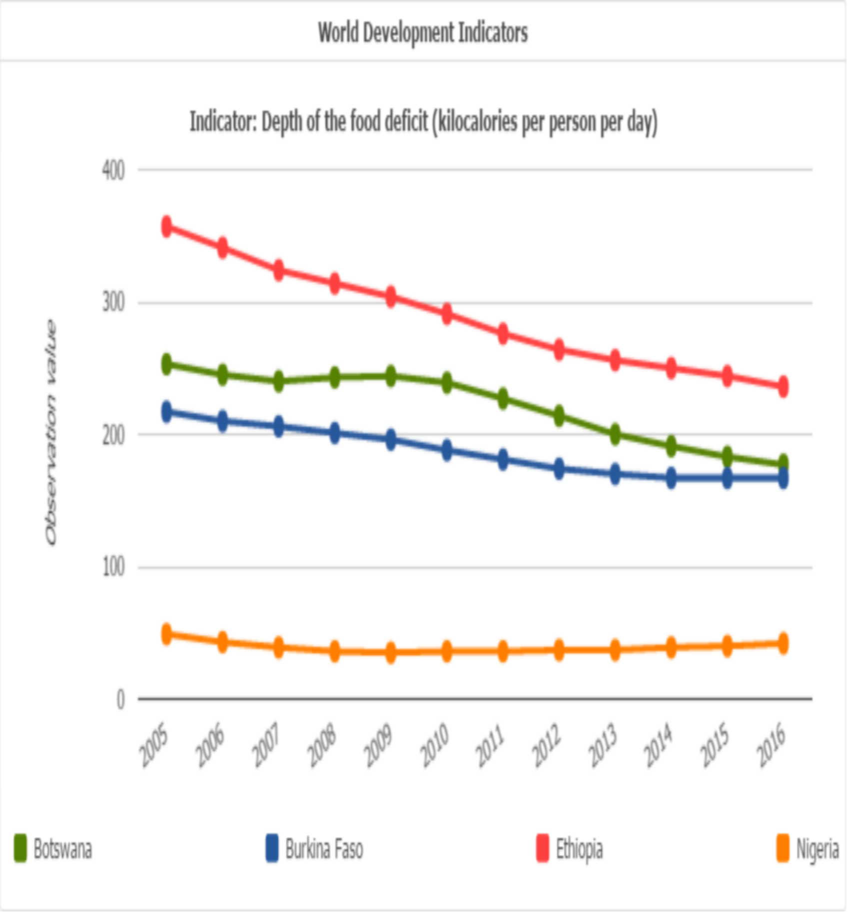
World Bank, Development Indicators

Public Health Approach

Another malaria glimpse:

Evolution some indicators associated with risk factors

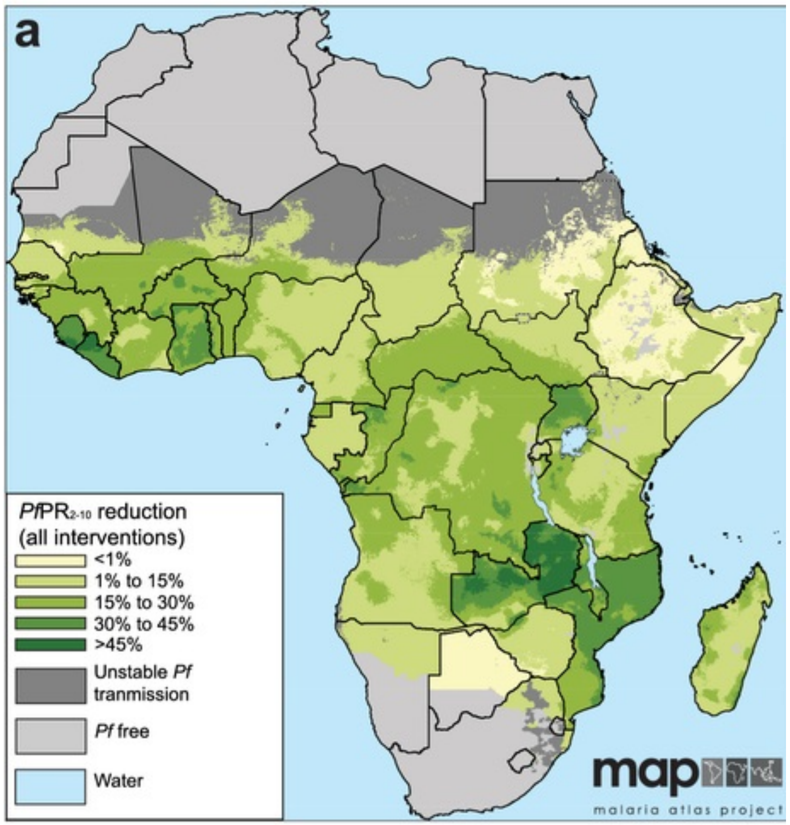




World Bank, Development Indicators

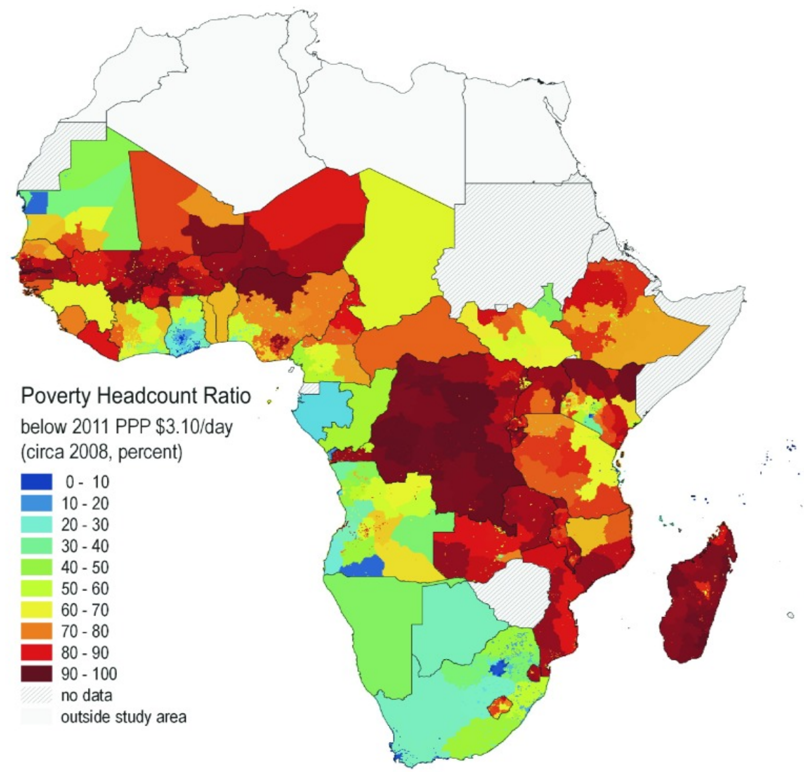
Public Health Approach
Another malaria glimpse:
Africa situation

Evolution: PfPR_2_10:
(2015 relative to 2000)



Bhatt, S., et al. (2015), Nature 526, 207–211
doi:10.1038/nature15535

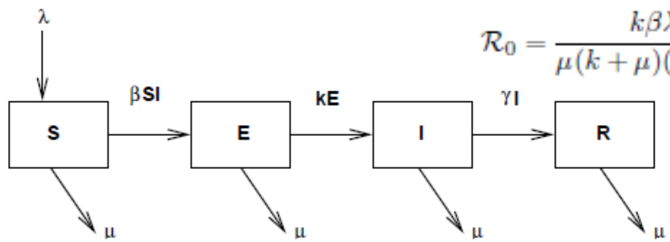
Poverty Indicator: 2011



Koo, J. et al (2016), F1000Research 5:2490
doi: 10.12688/f1000research.9682.1

Climate and Public Health issues:

How to close the information gaps?



$$\mathcal{R}_0 = \frac{k\beta\lambda}{\mu(k+\mu)(\gamma+\mu)}$$

SEIR Model: {S}usceptible-{E}Exposed-{I}nfectious -{R}ecovered

$$\frac{dS}{dt} = \lambda - [\Phi + \mu]\, S$$

$$\frac{dE}{dt} = \Phi\, S - [\mu + \kappa]\, S$$

$$\frac{dI}{dt} = \kappa\, E - [\gamma + \mu]\, I$$

$$\frac{dR}{dt} = \gamma\, I - \mu\, R.$$

$$\Phi = \beta\, I$$

$$\beta = \tau\, \upsilon$$

λ : *crude birth rate*

μ : *death rate*

γ : *recovery rate*

β : *transmission rate*

κ : *progression rate* : $E \rightarrow I$

Φ : *force of infection*

τ, υ : *transmissibility, contact rates*

- All infectious diseases (ID) cases must be notified, epidemiologically investigated and centrally registered .
- There is a need to either organize or/and to gather under GPS standards data on diseases, cases, vectors, parasite, interventions and risk factors under a proper temporal framework.
- For the math-models, climatic factors will continue to be highly important (extrinsic factor) , but, all remaining risk factors are also important to be consider. For example: intervention {clean water, sewage, IBN…} => recovery, contact, transmission rates).
- Allocation of resources for Public Health and other institutions associated with the surveillance of CD should be prioritize.
- Special efforts should be done regarding incorporating local risk factors conditions to models, to try to explain successful or unsuccessful disease risk management among different spatial units.

“The way we understand the causes or origin of disease and health defines the way we act on them "

Thank you!

Reference (associated with the public health practices and policy issues)

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