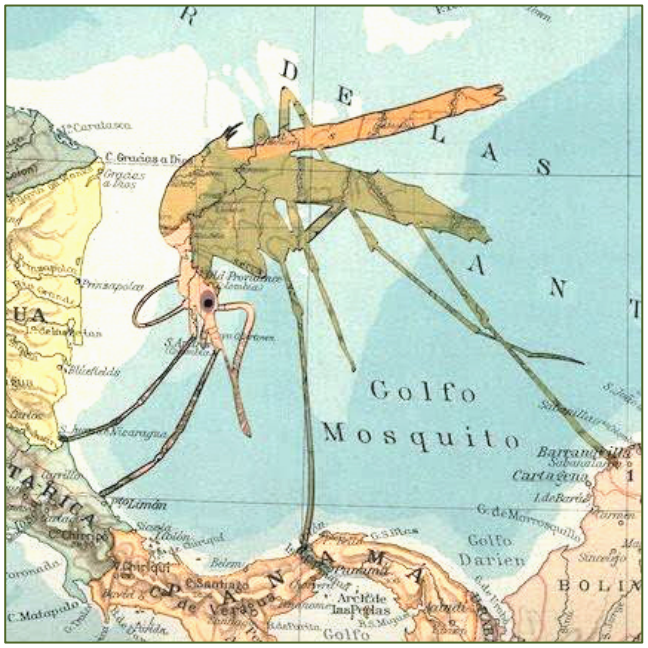
a quantitative history of malaria in maps



Dr Ewan Cameron, PhD
Malaria Atlas Project

timeline of malaria/malariology

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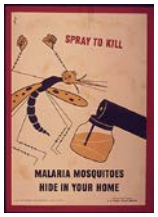

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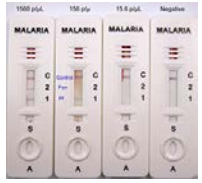

Millennium Development Goals Era

The Present

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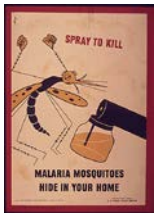

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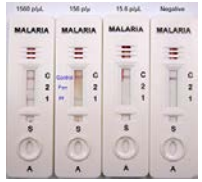

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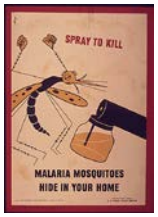

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available maps? Lysenko, few historical maps

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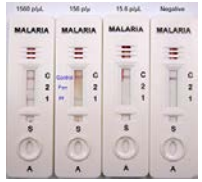

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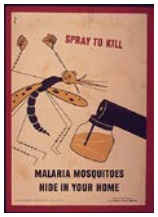

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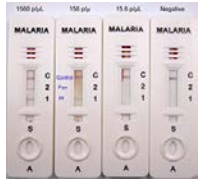

Millennium Development Goals Era

The Present

available maps? prevalence/incidence, interventions, MARA/MAP/WHO ...

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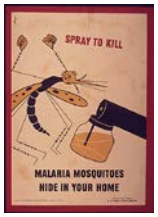

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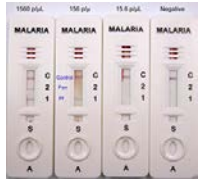
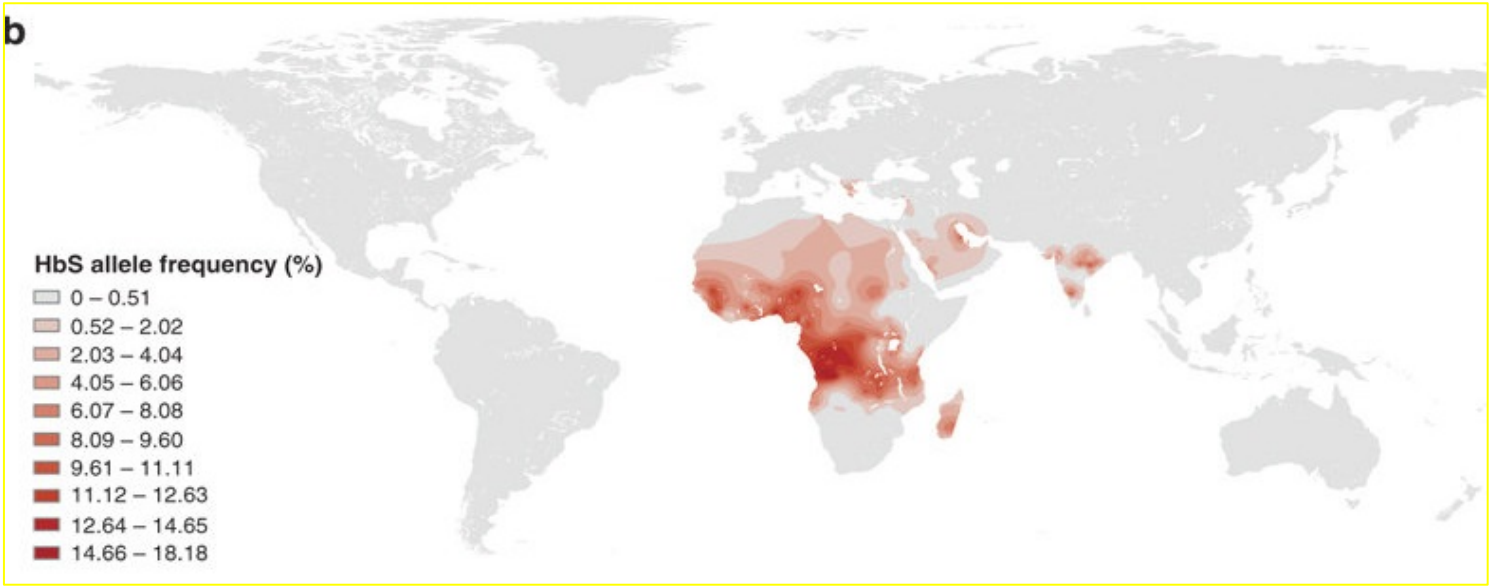


Millennium Development Goals Era

The Present & Future

available maps? projections under new interventions, drug resistance, …

malaria pre-microscopy: genetic maps



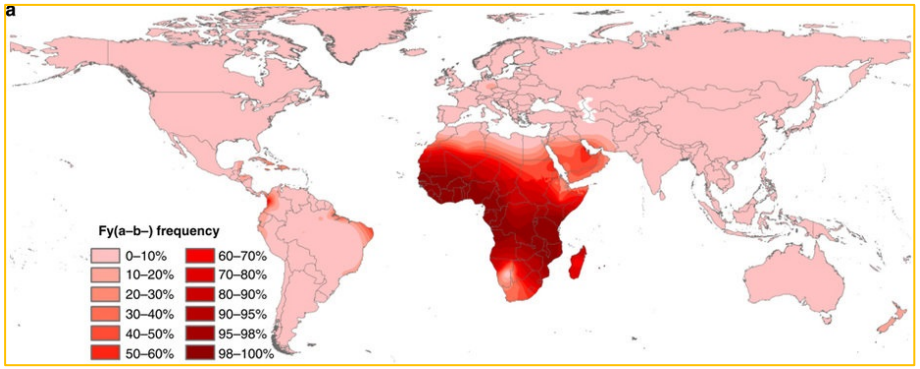
Piel et al., 2010, Nature Communications, 1, 104

- *emergence <5000-10,000 years ago (Hedrick 2012)*

- maps of the sickle haemoglobin allele frequency suggest a historical exposure to *Pf* malaria at the population level

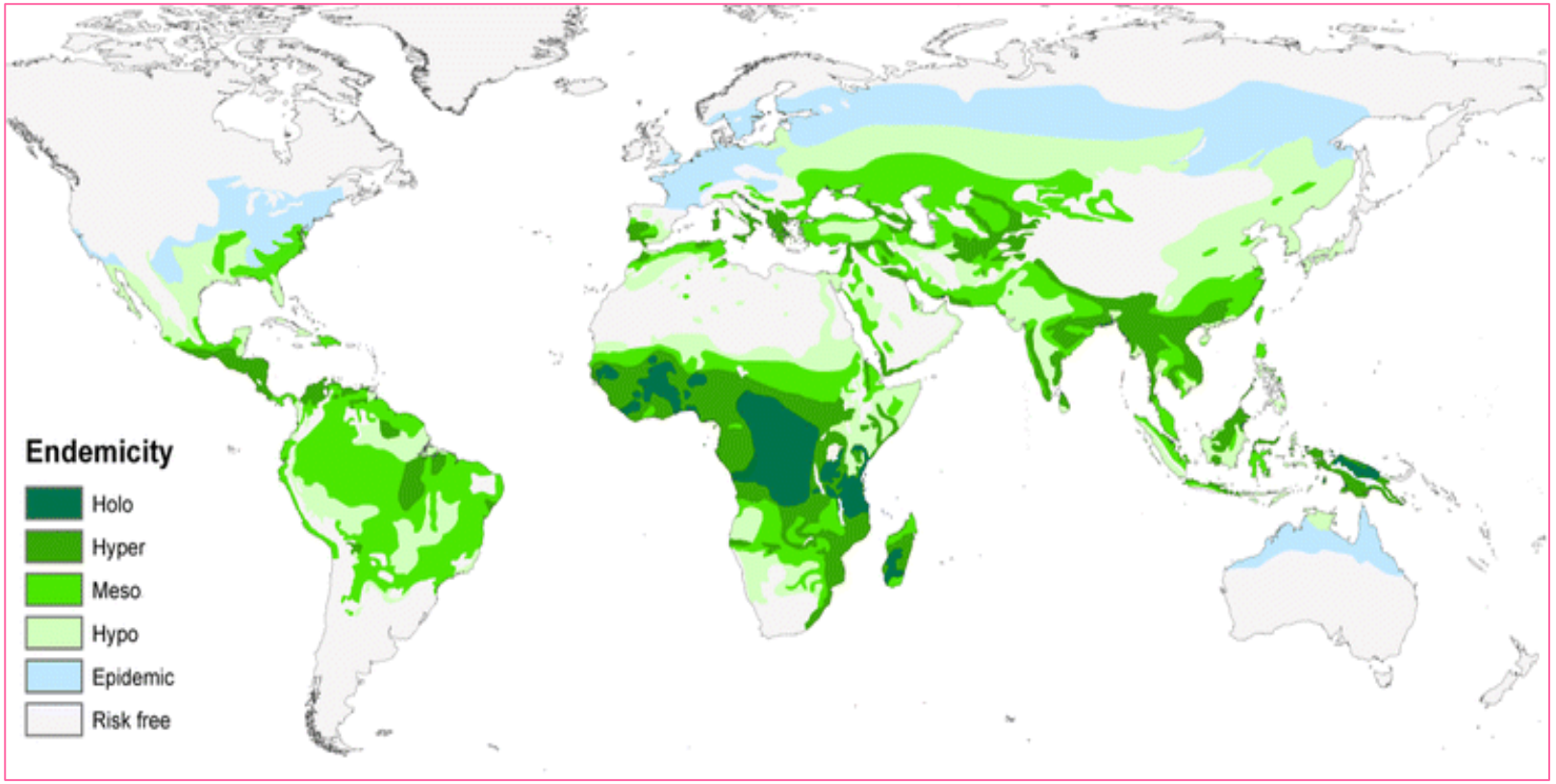
- hypothesis of balancing selection (protection vs SCA)

- likewise for *Pv* w/ maps of Duffy negativity



Howes et al., 2011, Nature Communications, 2, 266

the Lysenko map: malaria endemicity pre-control



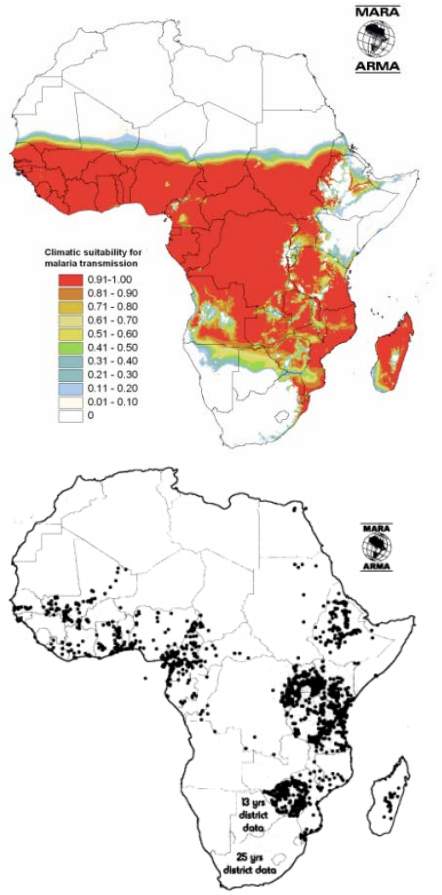
Lysenko & Semashko, 1968, Itogi Nauk Med. Geogr., 25, 146

Hay et al., 2004, Lancet Infectious Diseases, 4(6), 327-336

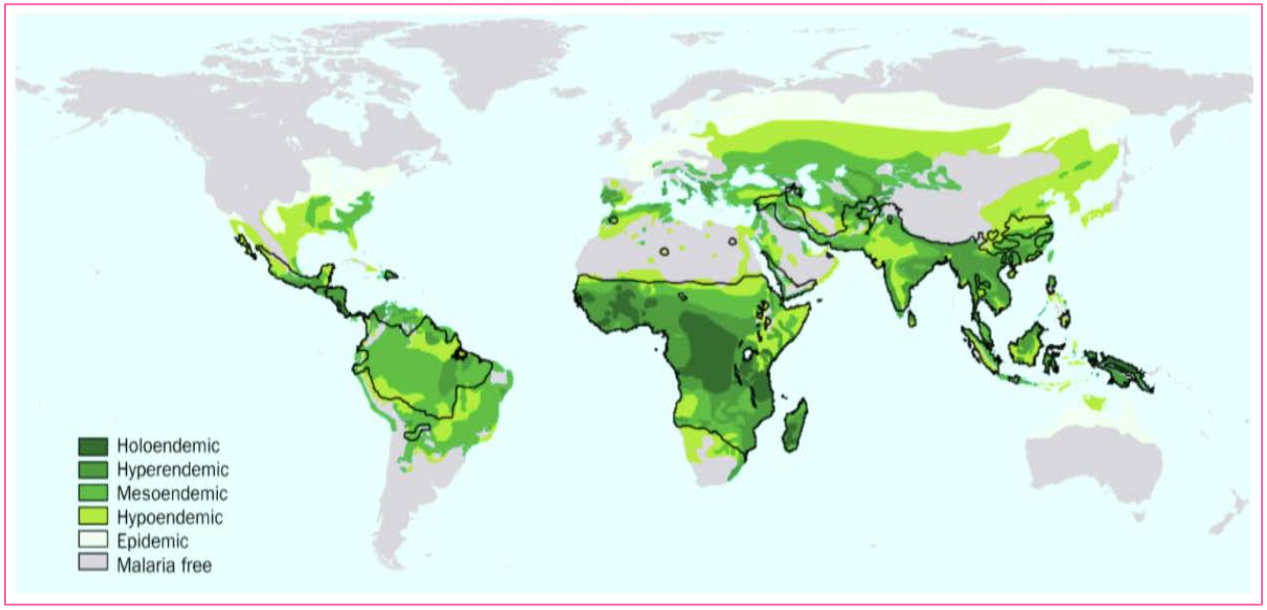
- hand-drawn synthesis of diverse sources: records of disease, vector presence / absence, prevalence data, sickle cell traits
- interpolation via expert opinion + isohyets of temp & rainfall

Lysenko map vs. post-GMEP stable limits

Climatic Suitability Index



Cox et al., 1999, MARA/HIMAL Technical Report

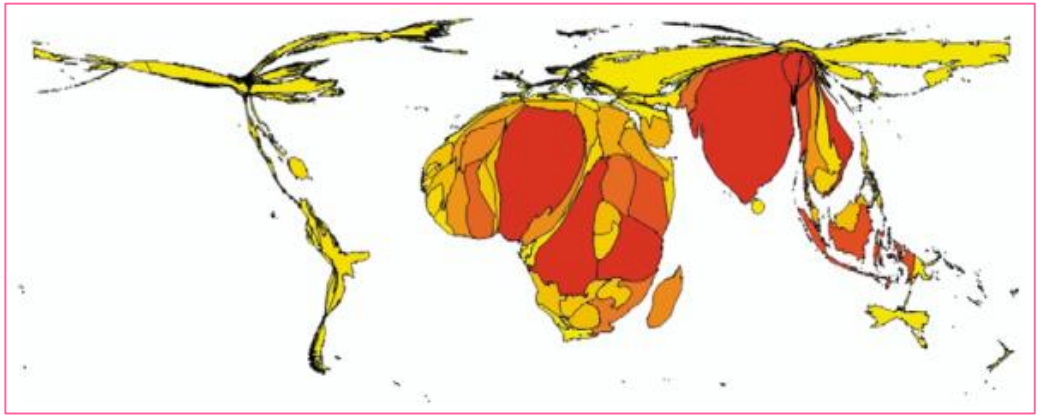


Hay et al., 2004, Lancet Infectious Diseases, 4(6), 327-336

- transmission limits at turn of century illustrate marked reductions in Europe, USA, & South America
- transmission limits in Africa bounded only by climatic suitability
- introduction of quantitative modelling: digital covariates, geo-positioned data, standard metrics

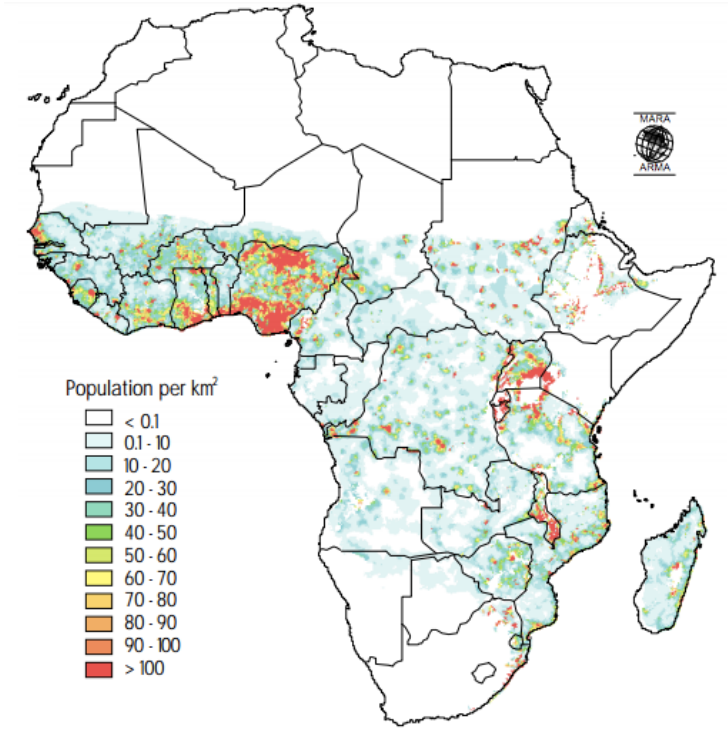
Lysenko map vs. post-GMEP stable limits

National Population Prevalence Cartogram



Hay et al., 2004, Lancet Infectious Diseases, 4(6), 327-336

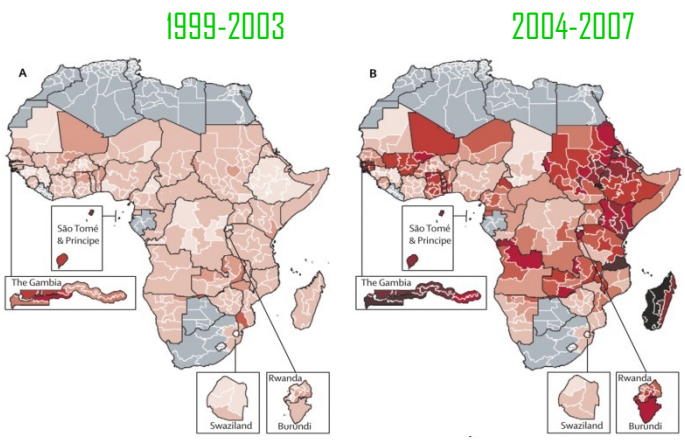
- *2002 estimate: 48% of global population "at-risk" (3 billion)*
- *projection to 2010: 3.4 billion*



Cox et al., 1999, MARA/HIMAL Technical Report

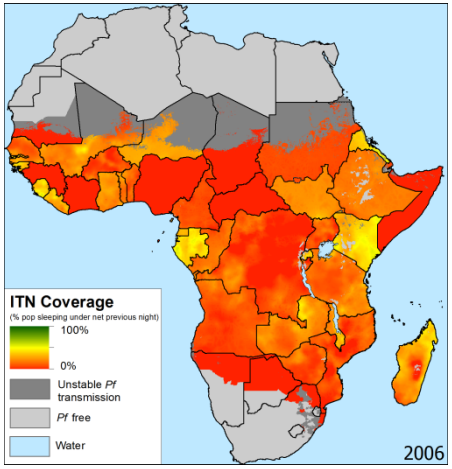
- growing understanding of disease burden due to malaria / increasing awareness of the scale of the problem
- malaria eradication back on the agenda: Roll Back Malaria (1998), Global Fund (2002)
- *beginning of the large-scale interventions …*

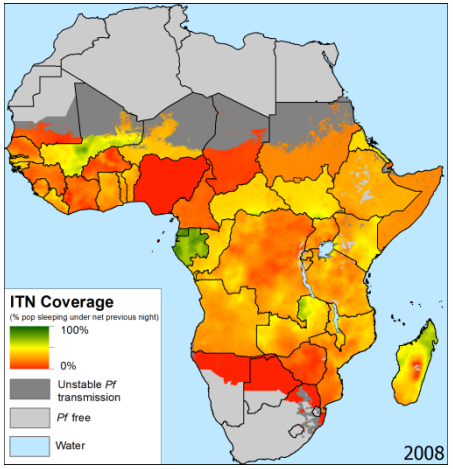
postmillennial scale up of ITNs in Africa

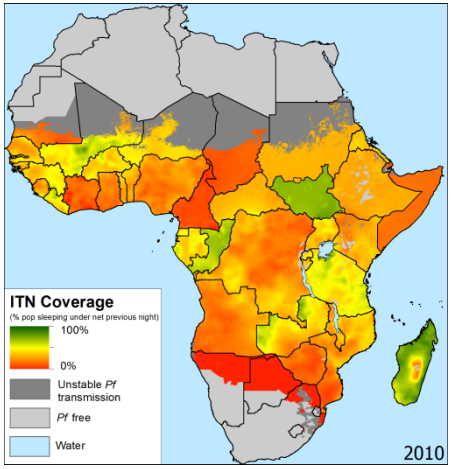


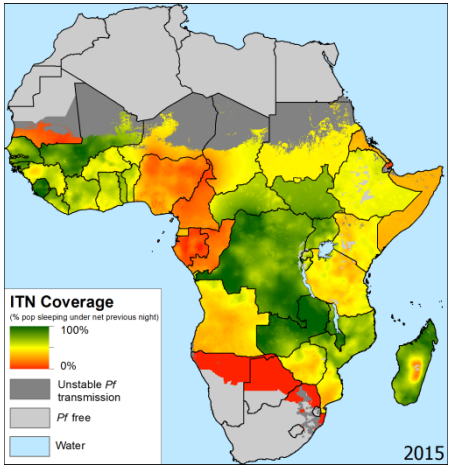
Noor et al., 2009, Lancet, 373, 58-67

- coverage of ITNs in Africa mapped through triangulation of use and net age data from household surveys, with manufacturer supply data









Bhatt et al., 2015, eLife, 4, e09672

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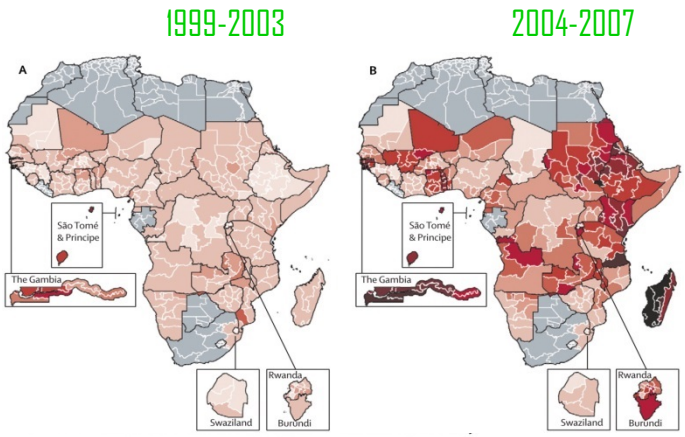

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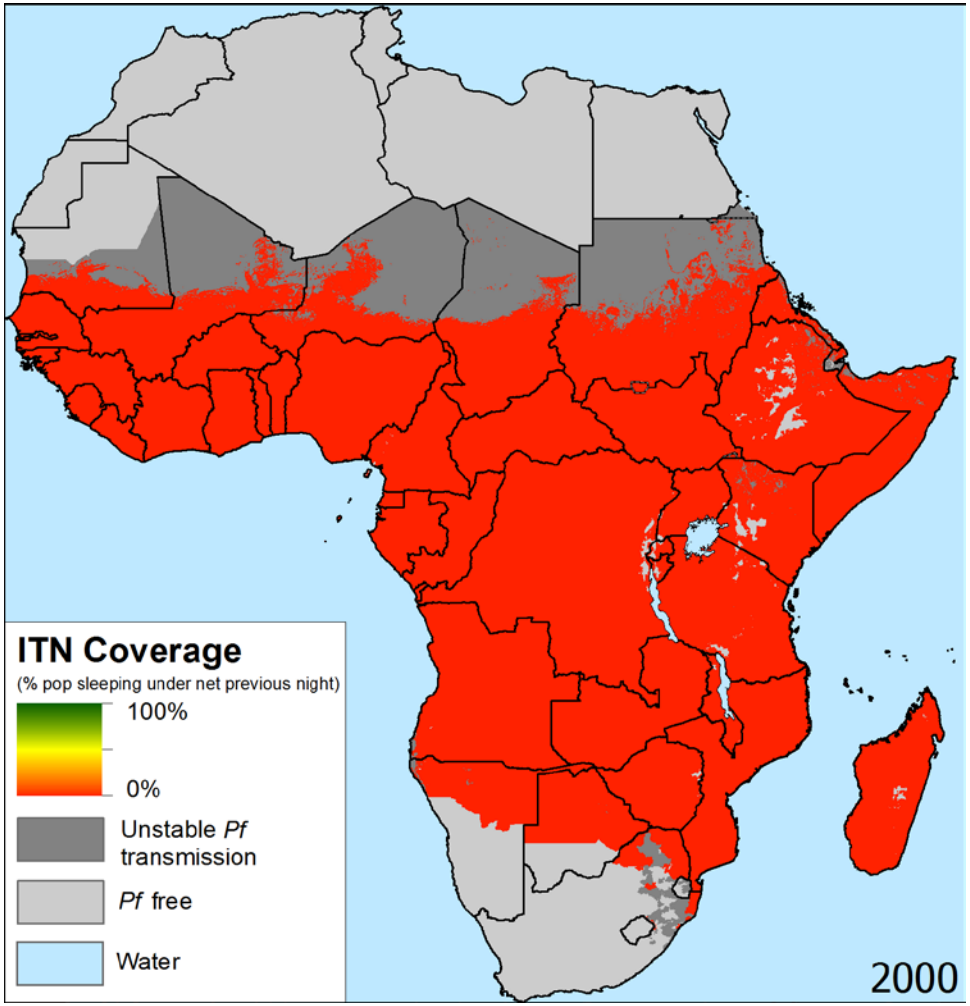

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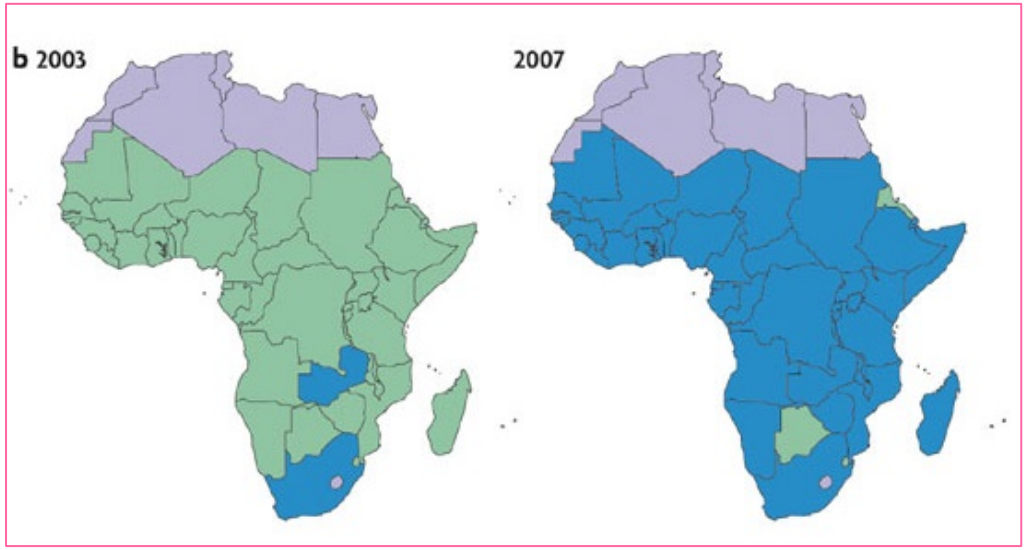
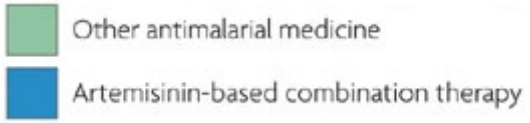
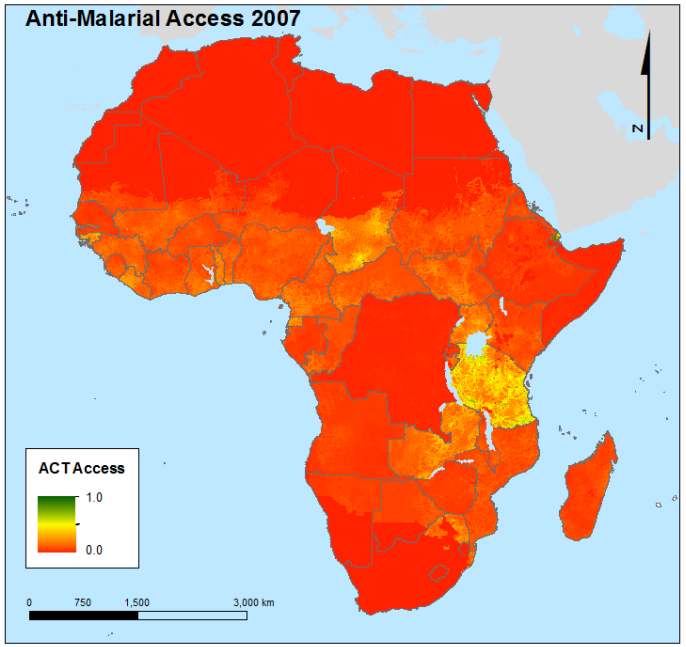
postmillennial adoption of ACTs in Africa

Firstline Anti-Malarial Policy





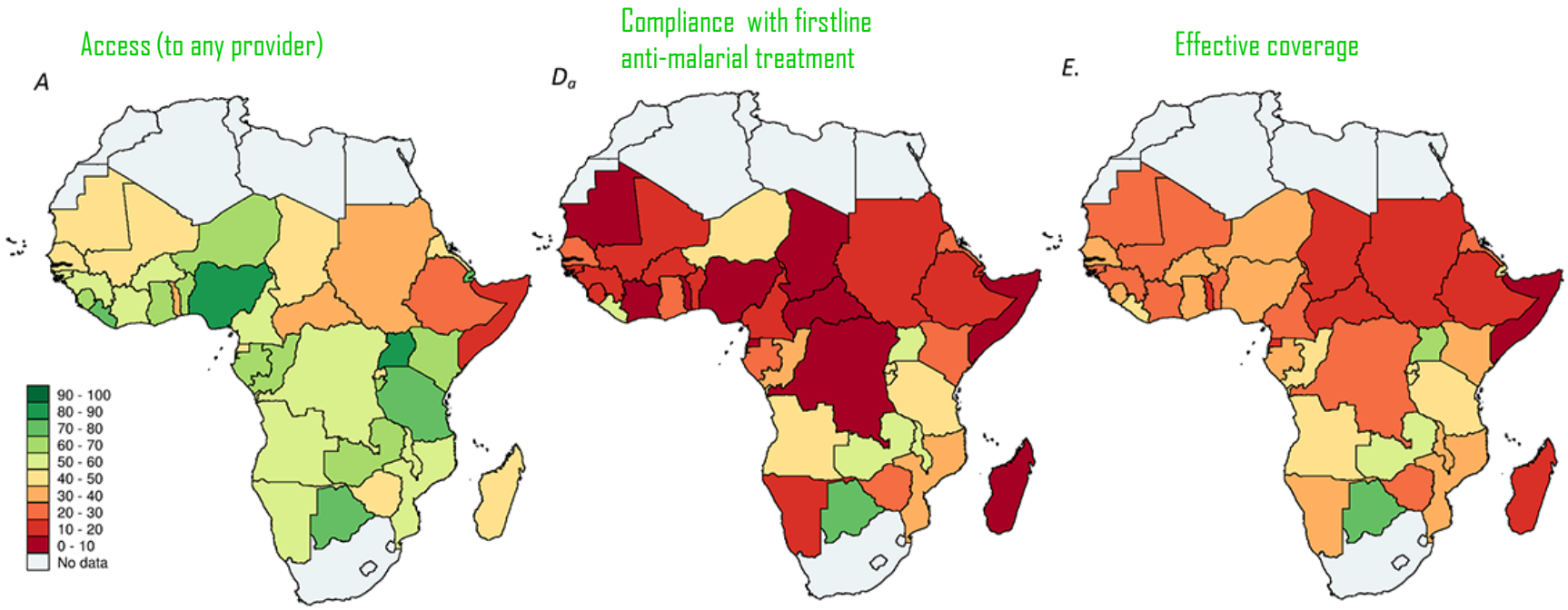
Eastman & Fidock., 2009, Nature Reviews Mic., 7, 864-876



Donal Biszanio (unpublished)

- frontline antimalarial policies widely switched to ACTs over 2003-2007 period
- access as measured by household surveys follows at varying rates across the continent

postmillennial adoption of ACTs in Africa



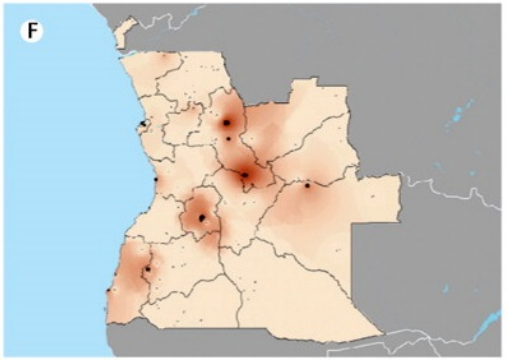
Galactionova et al., 2015, PLoS One, 0127818

- reasons behind lagging coverage show marked inter-country variation: access to care? healthcare providers follow guidelines? counterfiet drugs? patient compliance with full treatment regimen?

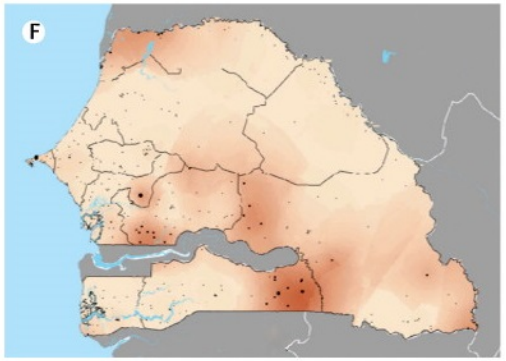
- allows identification of most promising interventions to improve health system efficiency

postmillennial application of IRS in Africa

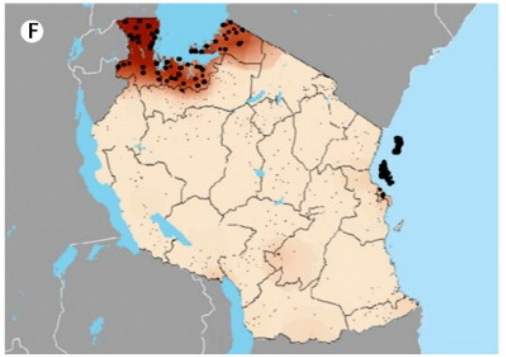
IRS Coverage: Angola



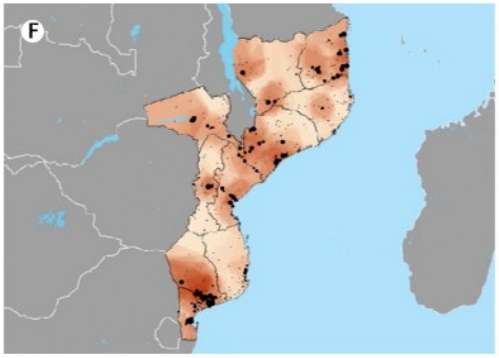
IRS Coverage: Senegal



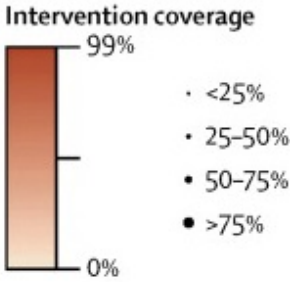
IRS Coverage: Tanzania

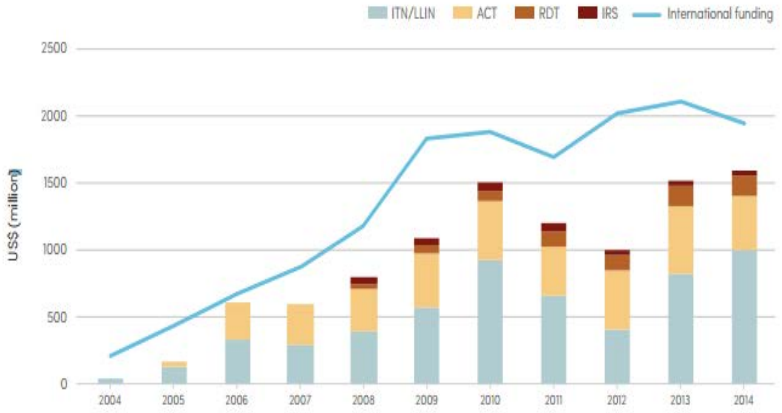


IRS Coverage: Mozambique



Giardina et al., 2014, The Lancet Global Heath, 2(10), 601-615





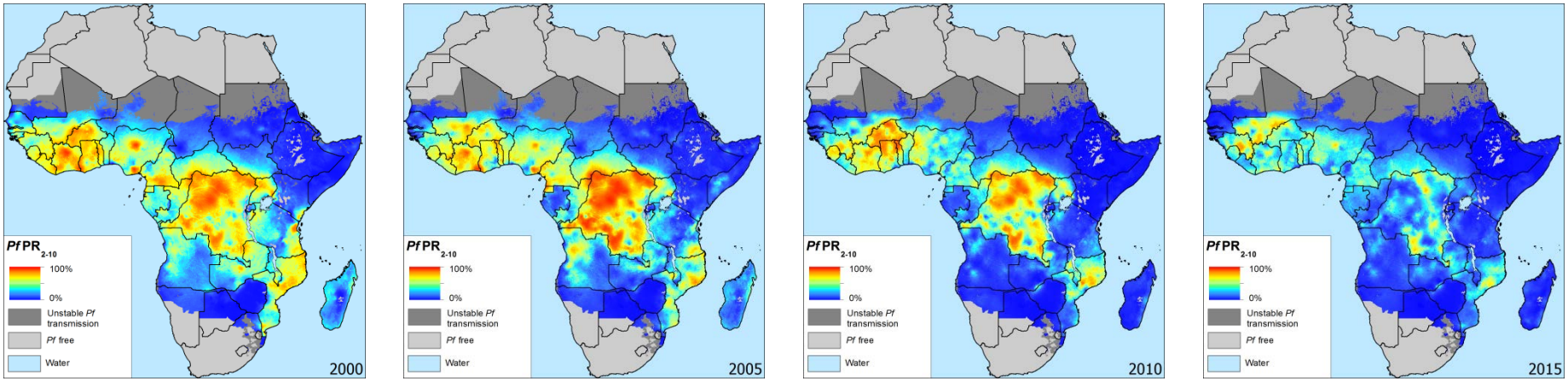
World Malaria Report 2015

- health surveys (also WHO assembled data) illustrate targeted application of indoor residual spraying in a number of African countries (funding ramped up since 2008)

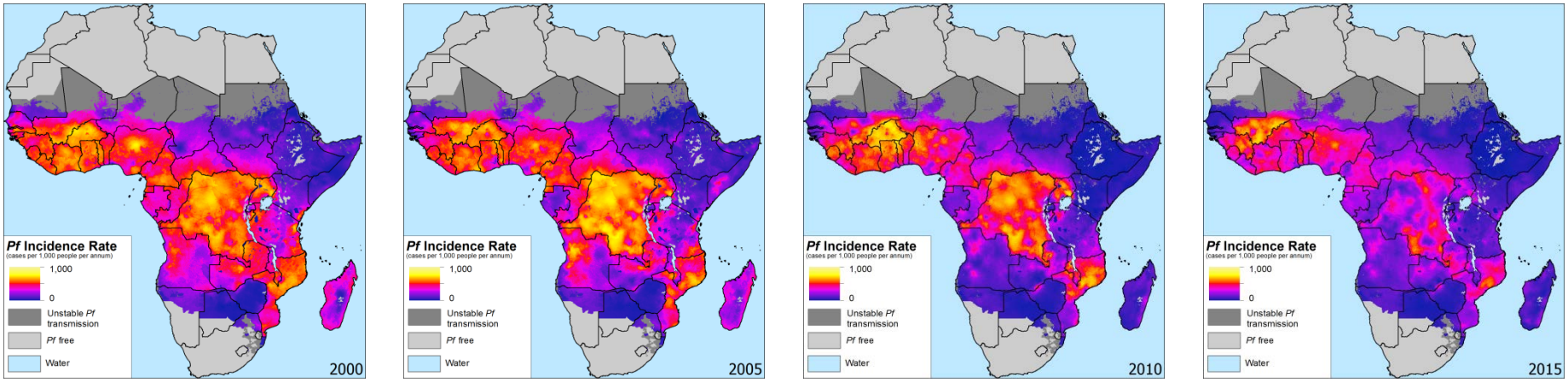
prevalence & burden declines in Africa: 2000-2015

- household surveys + model-based geostatistics confirms progress over the past 15 years!

Parasite Prevalence (Age Standardised 2-9 y/o) (%)



Incidence Rate (#Clinical Cases per 1000 PYO)



Bhatt, Weiss, Cameron et al., 2015, Nature, 526, 207-211

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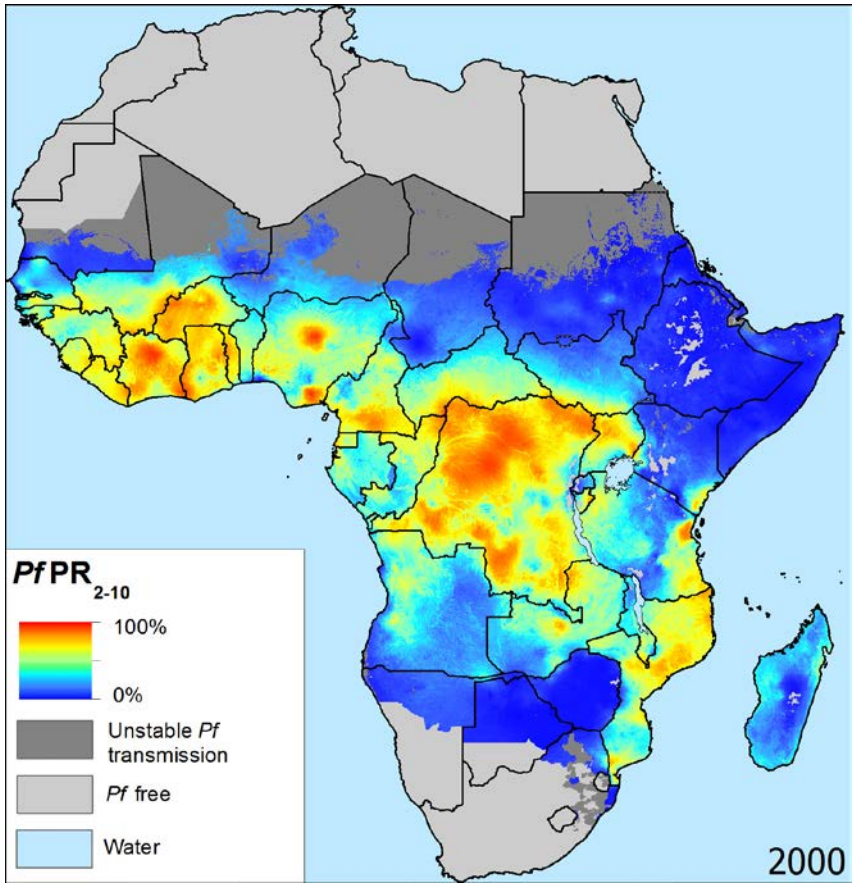

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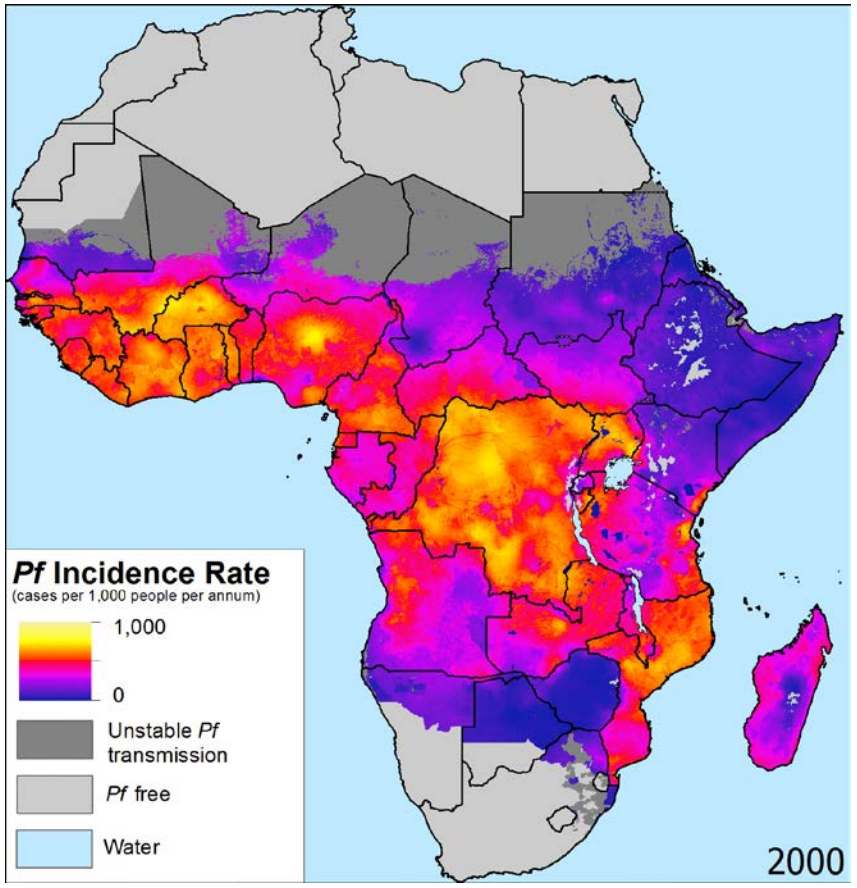

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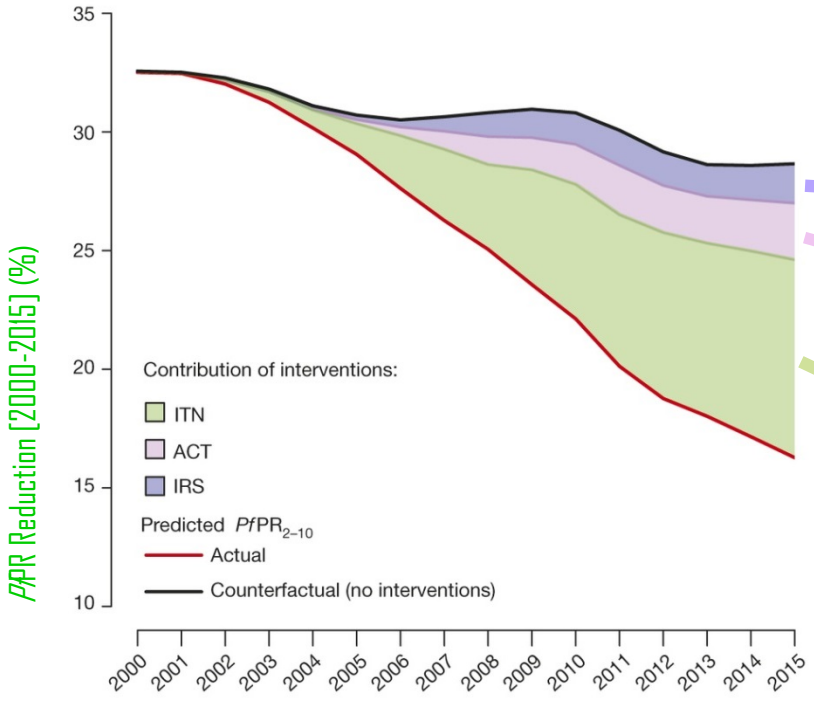
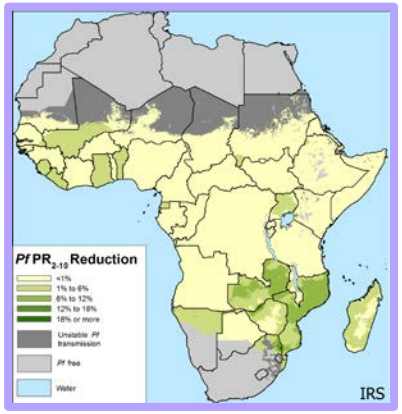
prevalence & burden declines in Africa: 2000-2015

- attributable impacts of the three major interventions identifiable from joint modelling of coverage history and prevalence over time

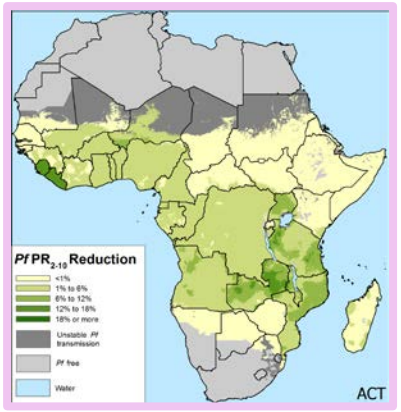


- relative contributions reflect relative funding, environmental suitability, coverage achieved, initial endemicity, etc.

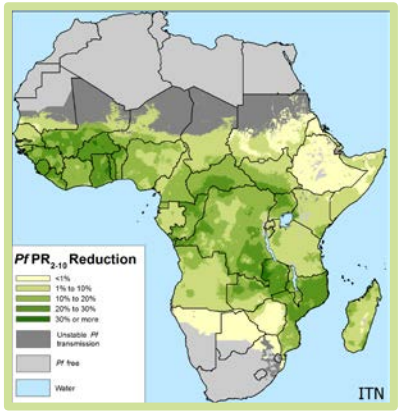
Indoor Residual Spraying



Artemisinin Combination Therapies



Insecticide Treated Nets

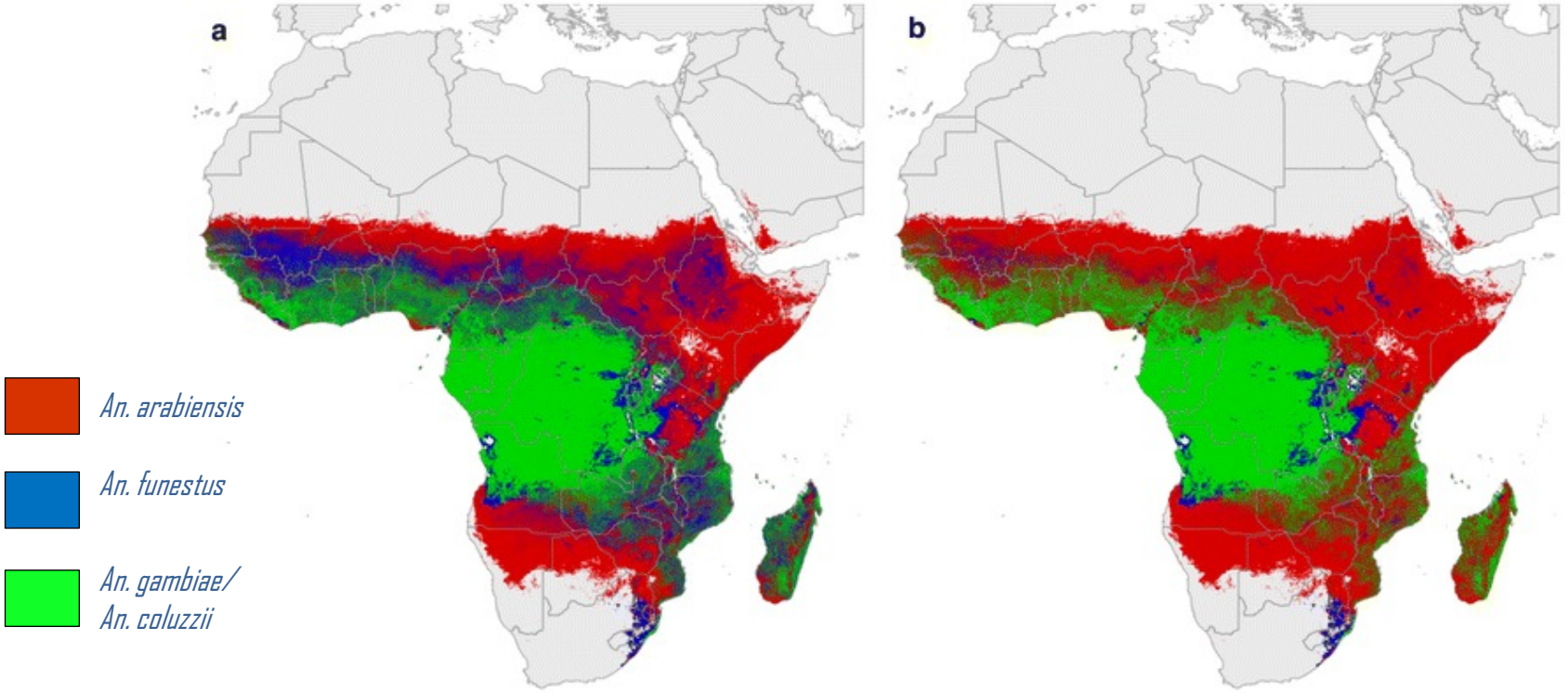


Bhatt, Weiss, Cameron et al., 2015, Nature, 526, 207-211

effects of vector control on species abundances

Relative Species Abundance: Pre-Intervention

Relative Species Abundance: Post-Intervention

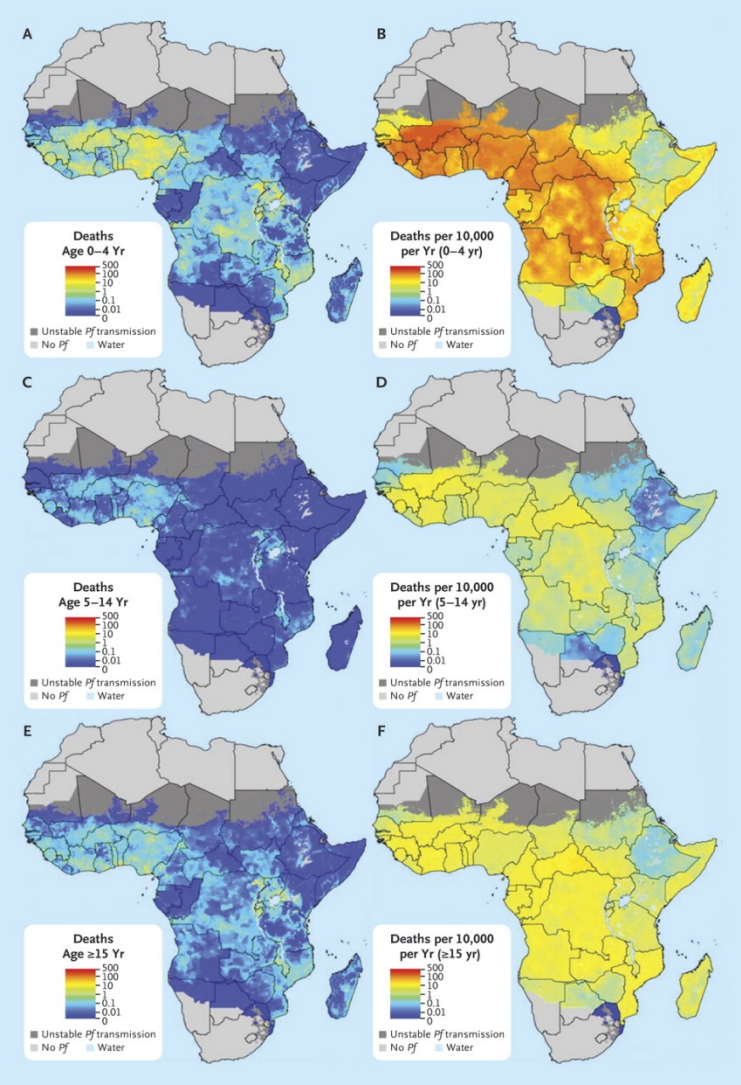


Sinka et al., 2016, Malaria Journal, 15, 142

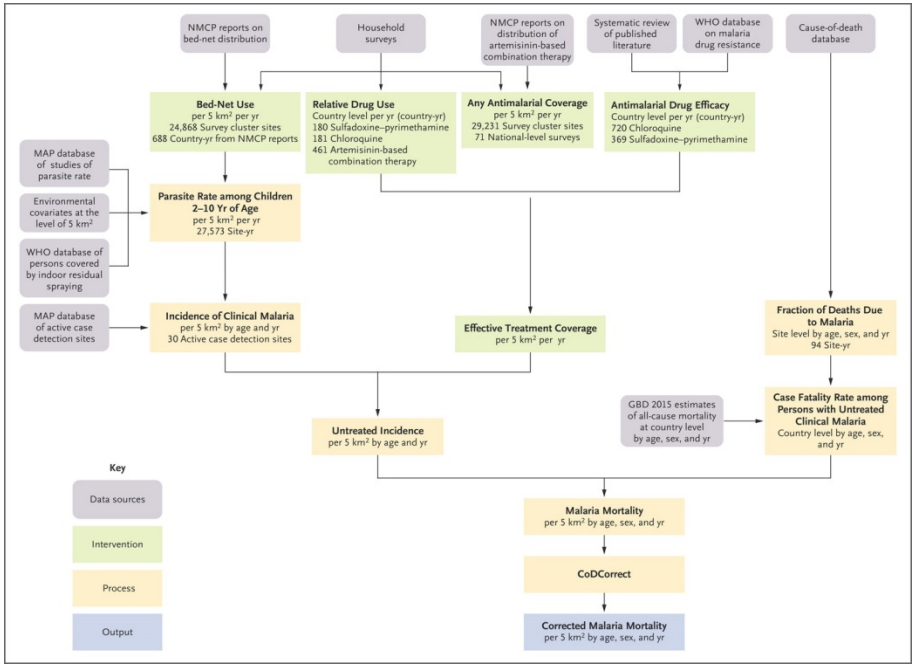
- impact of indoor-based insecticide interventions seen in change of vector species relative abundances

- relative susceptibility of funestus vs arabiensis: a role for future outdoor-based interventions?

2015 in review: malaria mortality in Africa

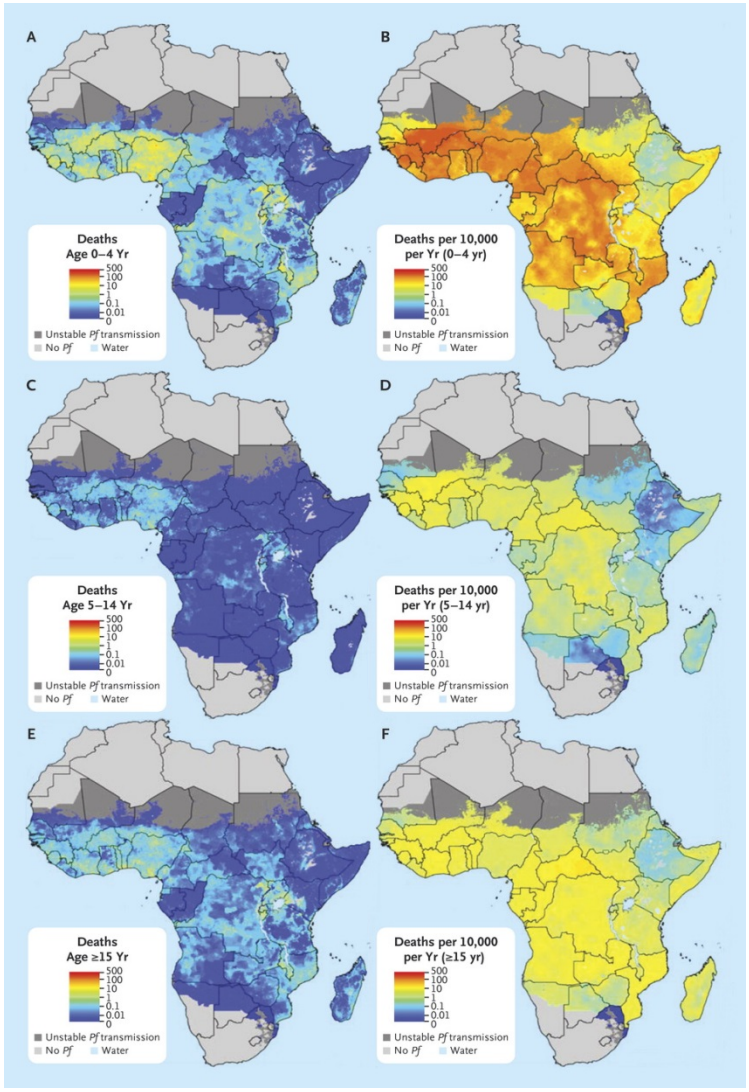


- spatial disaggregation of national-level mortality estimates (IHME; verbal autopsy) via incidence and treatment surfaces
- highlights heterogeneities between & within countries

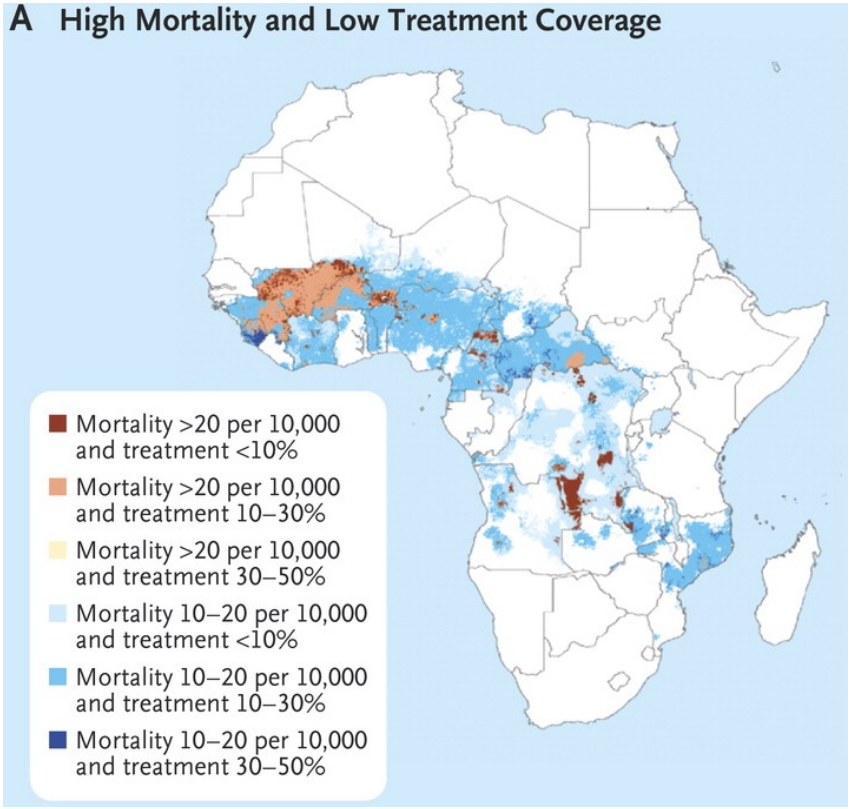


Gething et al., 2016, New England Journal of Medicine, 1606701

2015 in review: malaria mortality in Africa



- detailed understanding of mortality important for the planning, implementation & refinement of control strategies



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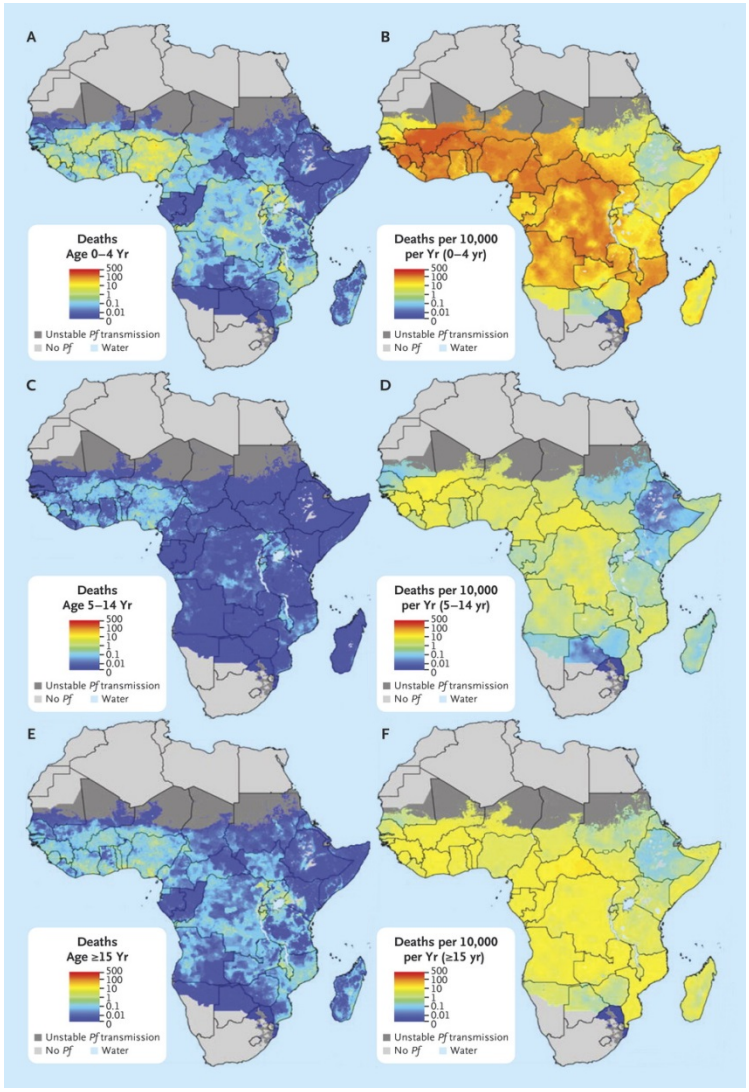

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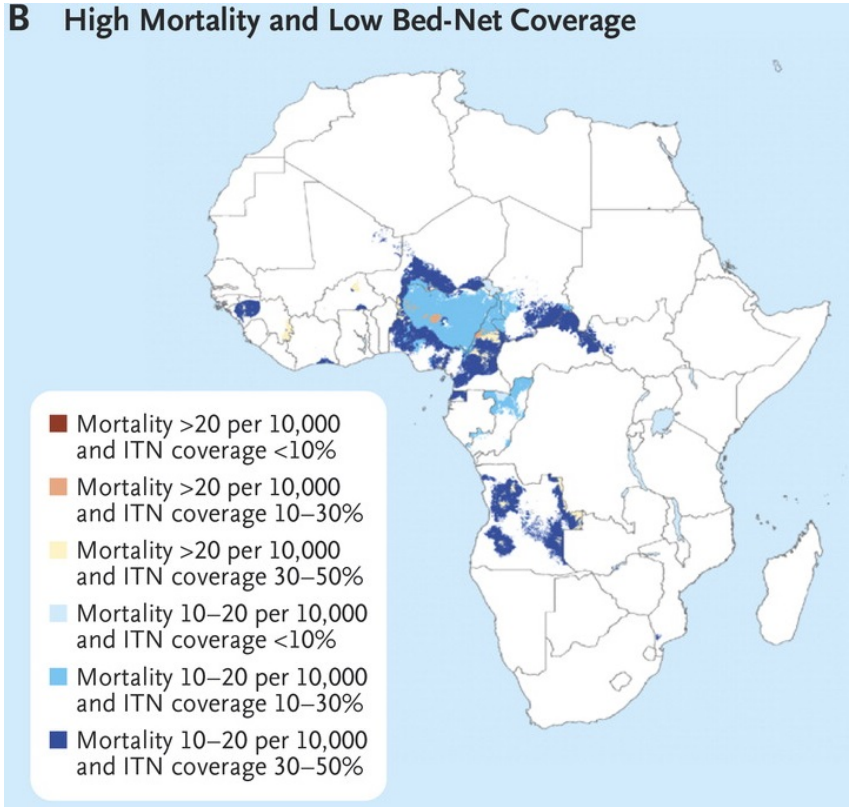
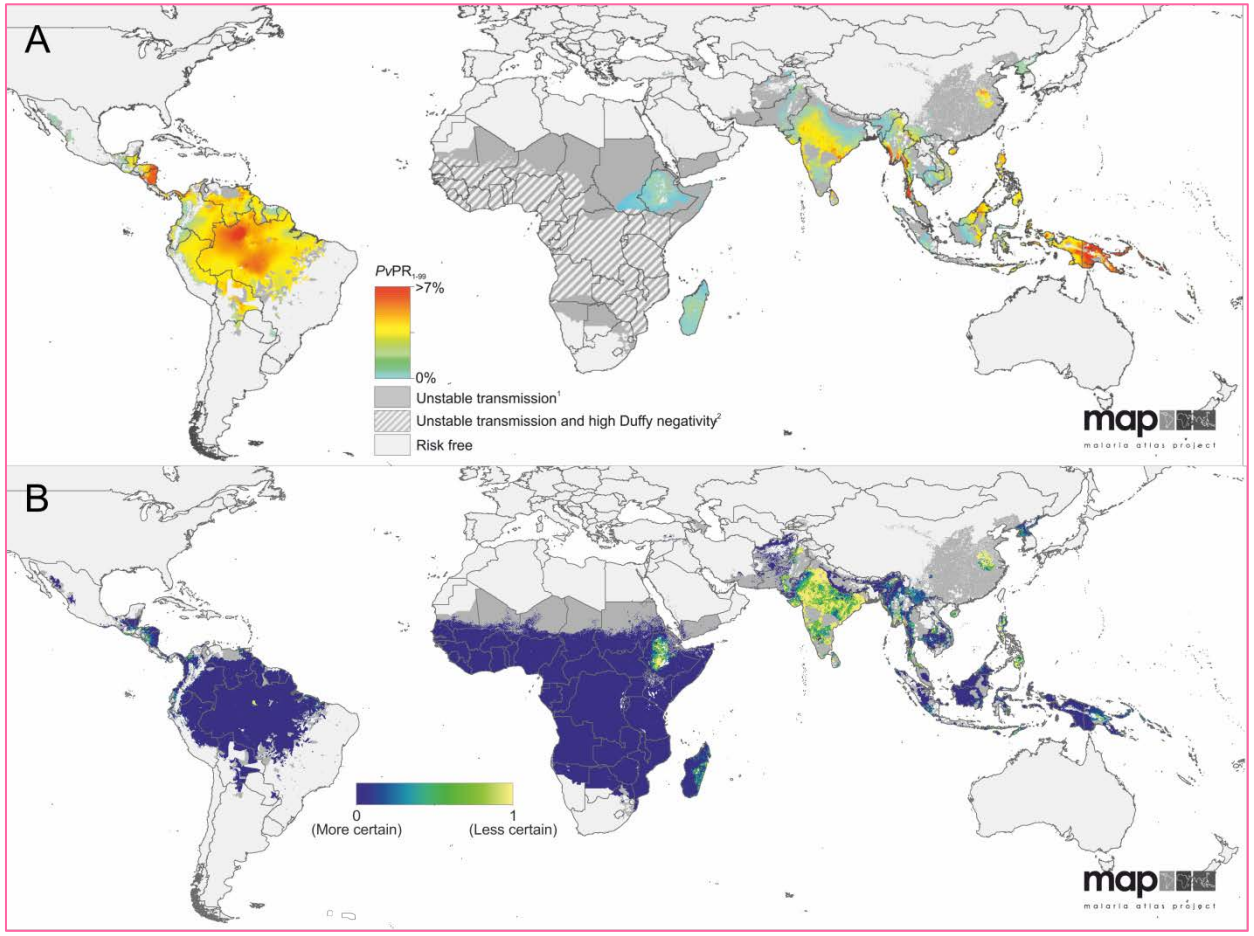


Gething et al., 2016, New England Journal of Medicine, 1606701

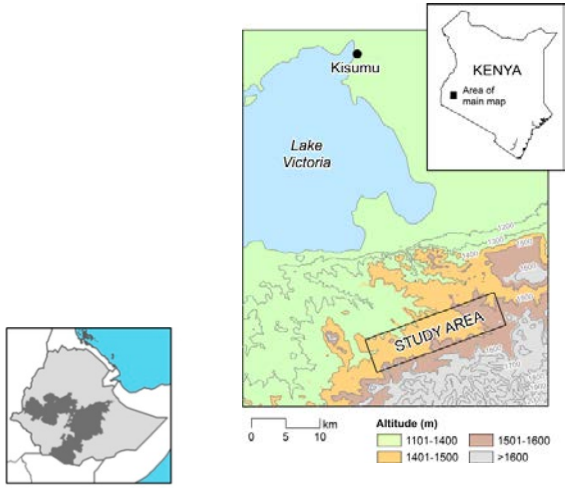
the *other* malaria map: *Plasmodium vivax*



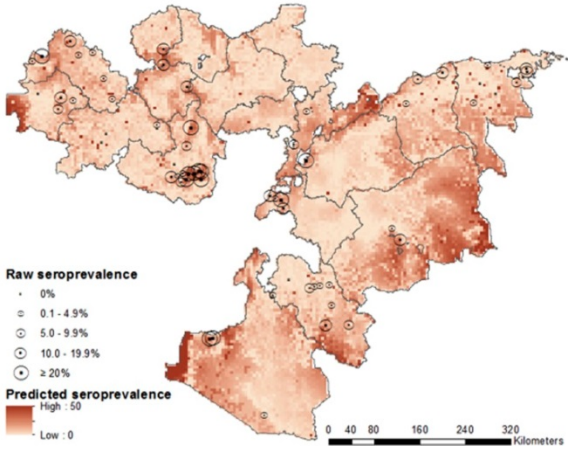
Howes et al., 2016, American Journal of Tropical Medicine & Hygiene, 95, 5

- mapping for burden enumeration of *Plasmodium vivax* steadily improving; as are mechanistic modelling tools

towards elimination: maps from alternative metrics

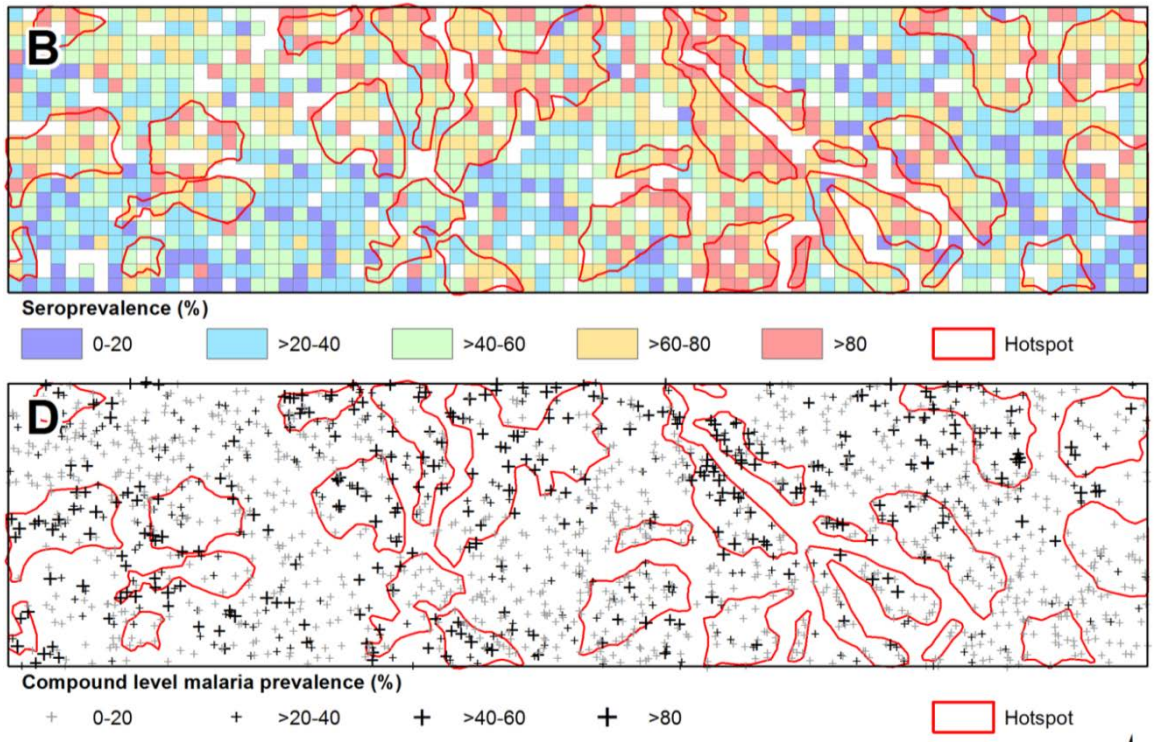


Sero-prevalence : Predicted



Ashton et al., 2015, Am. J. Trop. Med. & Hyg.,, 93(1) 168-177:

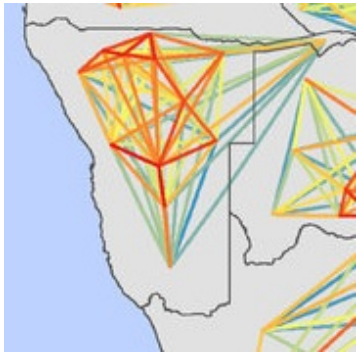
Sero-prevalence : Empirical



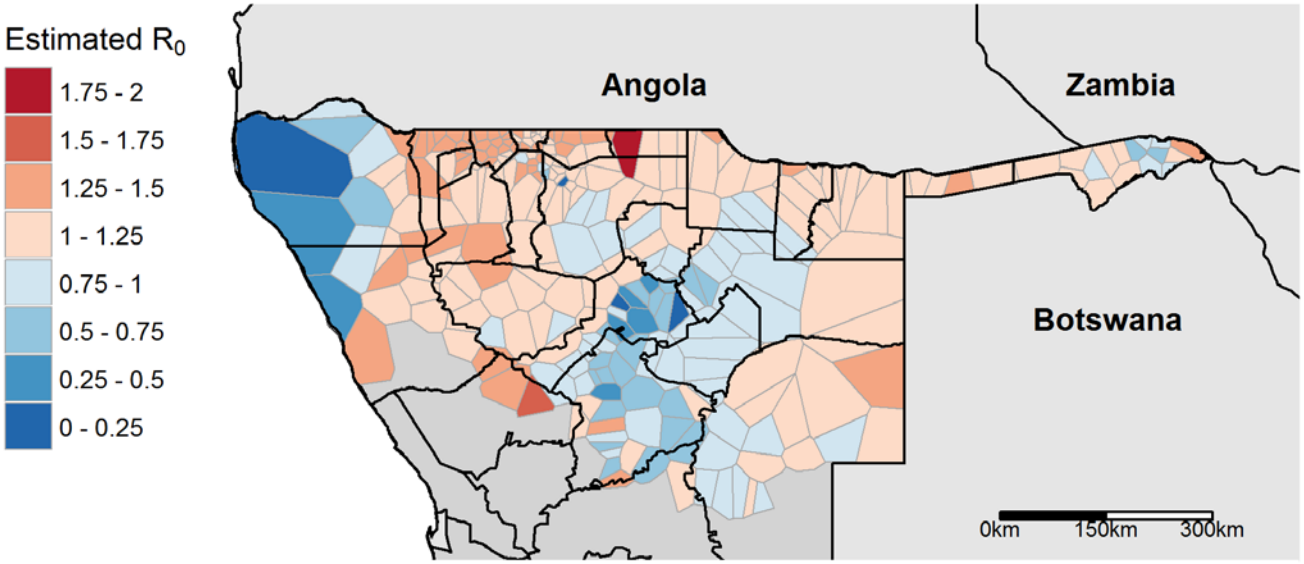
Bousema et al., 2016, PLoS Medicine, 1001993

- in the low transmission regime: a greater role for alternative malaria metrics: e.g. serology
- challenge is to estimate SCR (ongoing work with Drakeley group)

towards elimination: maps from alternative metrics

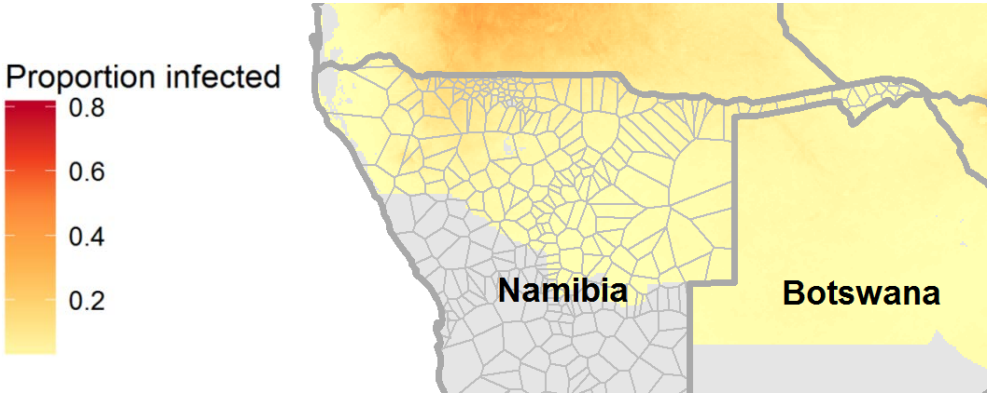


Sorichetta et al., 2016, Scientific Data, 3, 160066



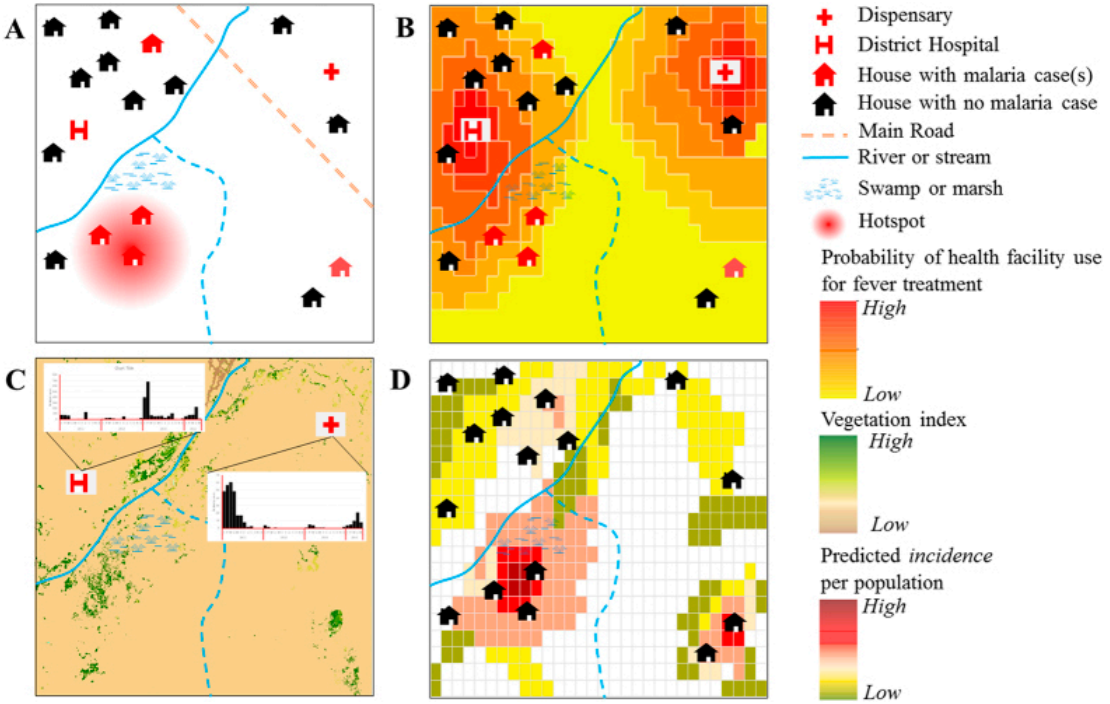
- the importance of human movement data: deconvolution of sources & sinks from observed prevalence surface

- also, a role for joint mechanistic – statistical studies: mapping at the level of the latent variable (joint work w/ Dave Smith & co)

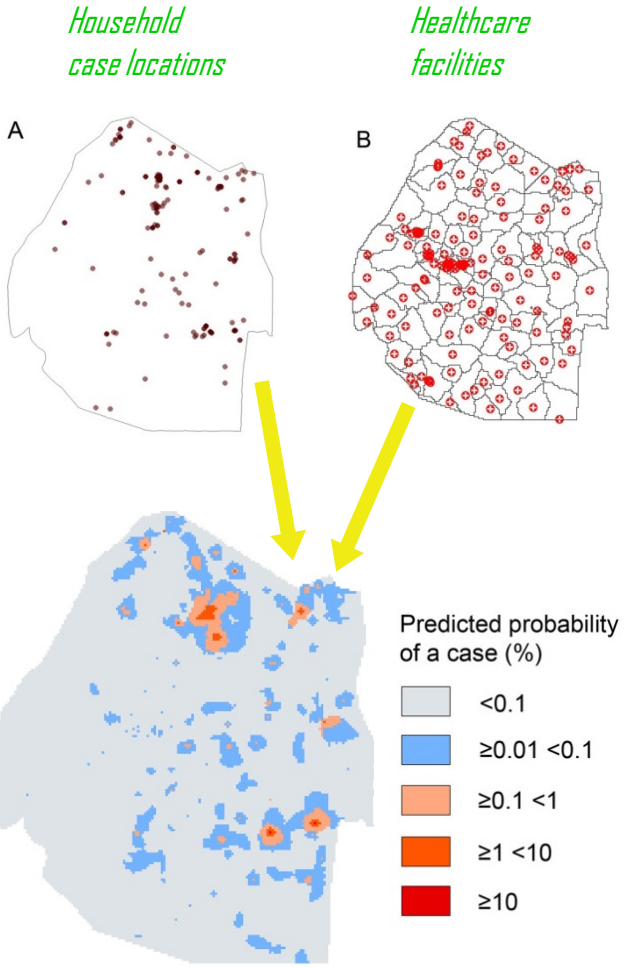


Ruktanonchai et al., 2016, PLoS Comp. Bio., 1004648

towards elimination: maps from alternative metrics



Alegana et al., 2016, Scientific Reports.,6,29628

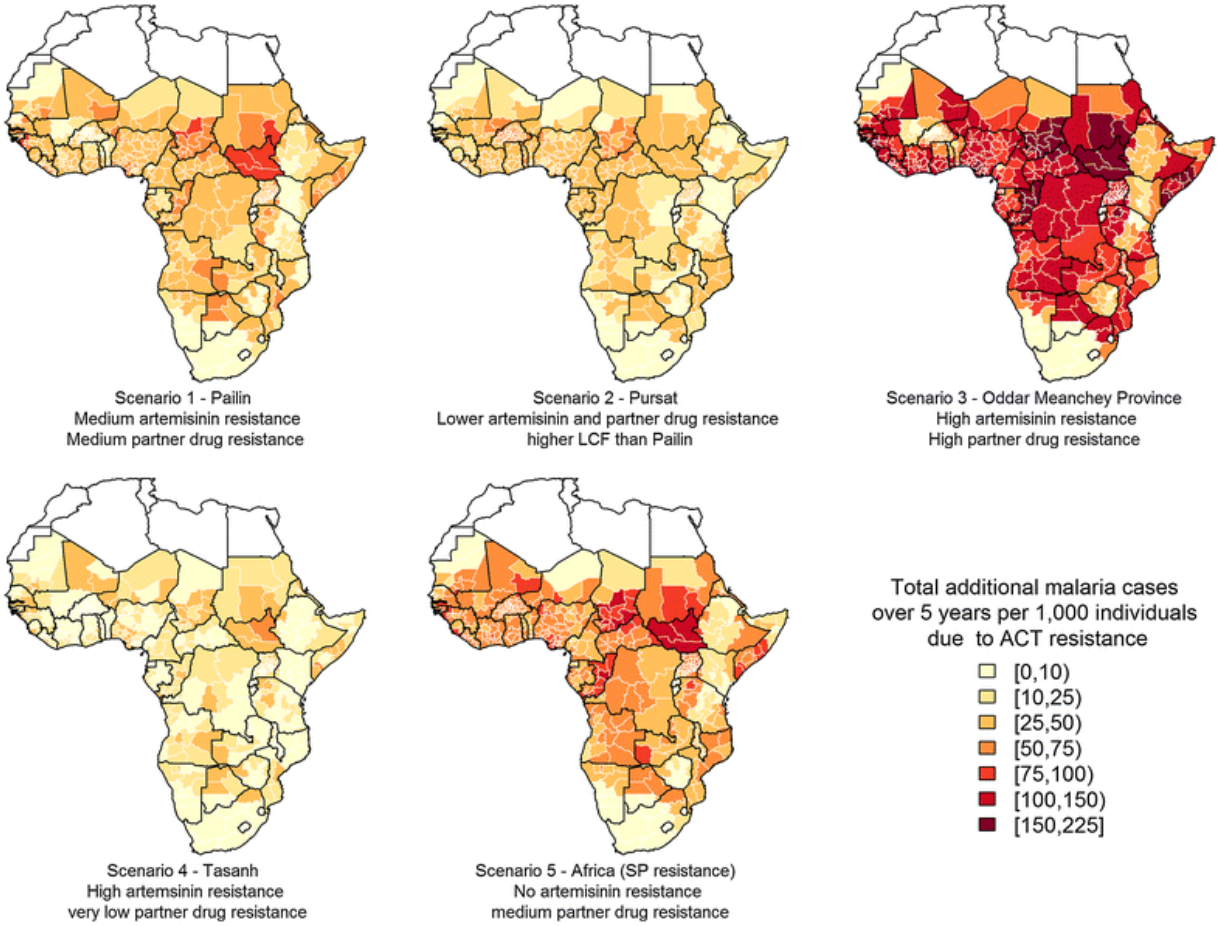


Sturrock et al., 2014, Malaria Journal.,13, 421

- catchment modelling: an increasingly important step to harness facility level case data

- at MAP: development of travel time surfaces (Dan Weiss) & statistical methodologies for joint API & point prevalence modelling (Tim Lucas)

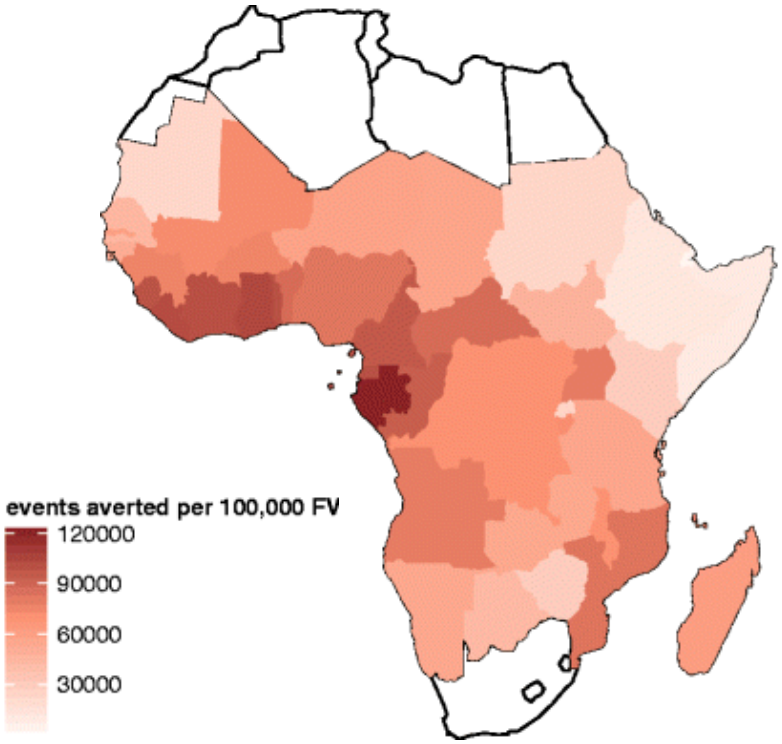
a possible future: insecticide resistance …



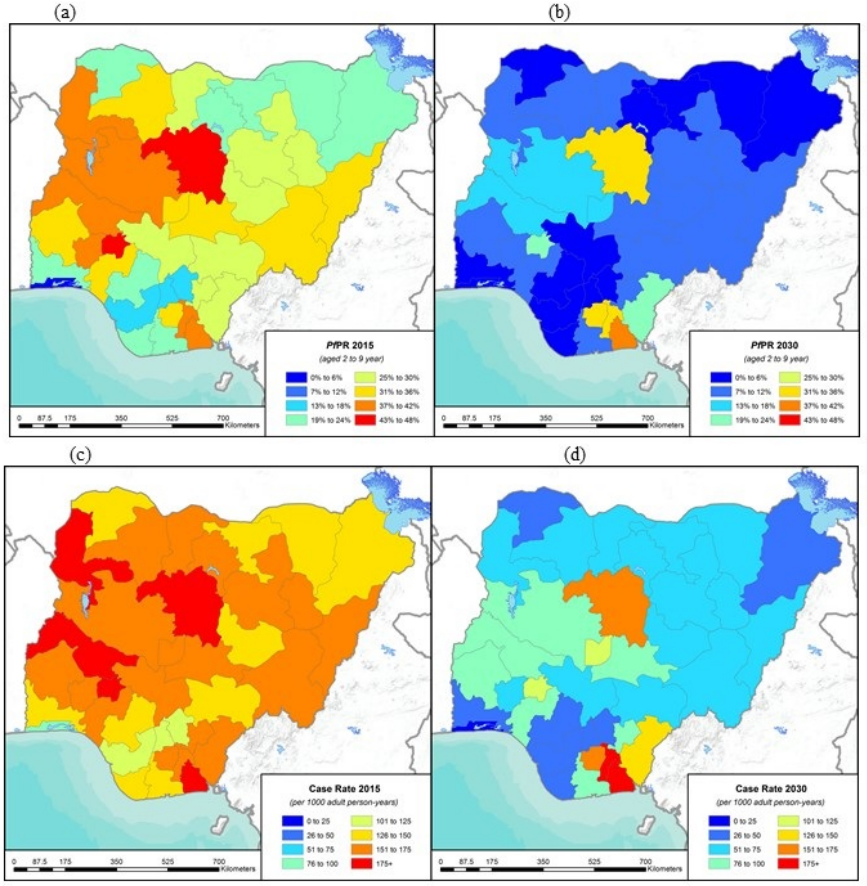
Slater et al., 2016, Malaria Journal, 15, 10

- maps for forecasting (& hopefully real-time monitoring) of risks / new challenges ….

a possible future: intervention deployments …



Penny et al., 2015, BMC Medicine, 13, 170

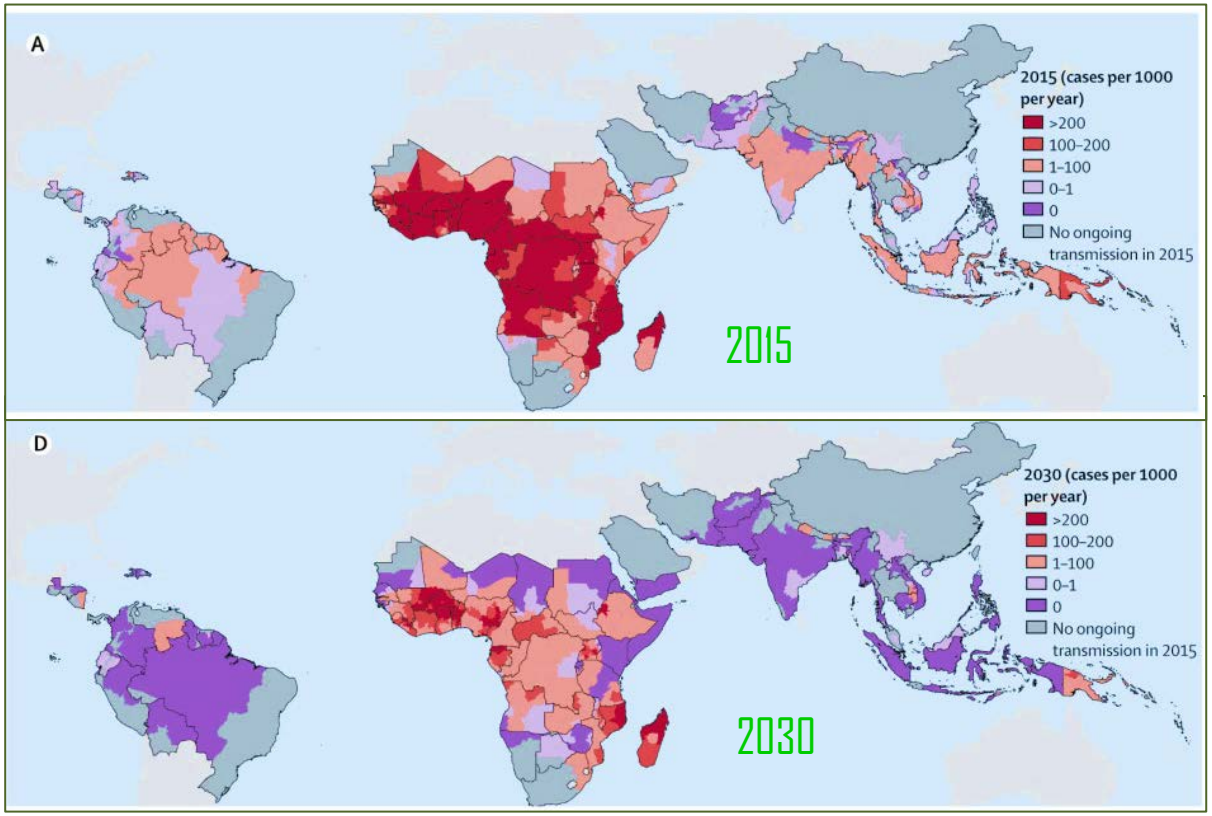


Korenromp et al. submitted (SPECTRUM-MALARIA)

- maps for understanding potential of RTS,S vaccine
- and for assisting program managers working at sub-national level (SPECTRUM-MALARIA)

a possible future 15 years from now …

Present day incidence vs model based forecast for 2030: increasing coverage (90%) + SMC



Griffin et al., 2016, Lancet Infectious Diseases, 16, 465-472

- power of maps for illustration & comparison of likely outcomes under future intervention plans (focus of Malaria Modelling Consortium)

the end

funders of the Malaria Atlas Project …

wellcome trust

BILL & MELINDA GATES foundation

MRC Medical Research Council