

# Estimating the impact of PMI's malaria control activities, 2005-2024



# Aim

To estimate and communicate the historical impact of the President's Malaria Initiative (PMI) on malaria burden across sub-Saharan Africa from 2005 to 2024, quantifying reductions in malaria cases and deaths as a result of PMI investments.

# Objectives

1. Generate estimates of PMI impact through 2024 across PMI-supported countries in sub-Saharan Africa (SSA).
2. Quantify malaria cases and deaths averted by comparing observed outcomes to a counterfactual scenario without PMI support.
3. Integrate results from two independent modelling groups (Imperial College London and Malaria Atlas Project).
4. Present high-level estimates of the historical impact of PMI.



# Summary | Key modelling findings

## Statement

## Key takeaway

1

PMI's activities have facilitated widespread delivery of core malaria interventions (ITNs, SMC, IRS, and ACTs) across diverse settings

- From 2005-2024, across 25 partner countries, on average PMI's greatest proportional contribution to increases in intervention coverage was to artemisinin combination therapy (ACT, 32.7%) followed by indoor residual spraying (IRS, 43.3%), insecticide treated bed-nets (ITNs, 18.0%), and seasonal chemoprevention (SMC, 11.4%).
- PMI made its **largest proportional contributions to the total coverage** of interventions in the period **2018-2020** reaching **72% for IRS, 28% for ITNs, 24% for ACTs, and 17% for SMC.**

2

PMI has contributed substantially to reductions in malaria transmission and mortality across partner countries

- During this period, the procurement and distribution of malaria interventions by PMI averted an estimated **379 million cases** (95% credible interval: 273, 606 million) and **1.1 million deaths** (95% credible interval: 0.7, 1.5 million).
- In 2024, the **incidence rate was 11.8% less** and the **mortality rate was 15.7% less** due to PMI activities.
- The **average cost per case averted was 18.6 USD** (95% credible interval: 11.6, 25.8 USD) and **per death averted was 6,205 USD** (95% credible interval: 4,587, 9,848 USD) when considering PMI spending on ACT, IRS, ITNs, and SMC.
- Results should be interpreted as PMI's contribution within a wider, coordinated financing context. Investment decisions were **taken jointly with national programmes and aligned with partner funding** with PMI support intentionally complementing other resources.

3

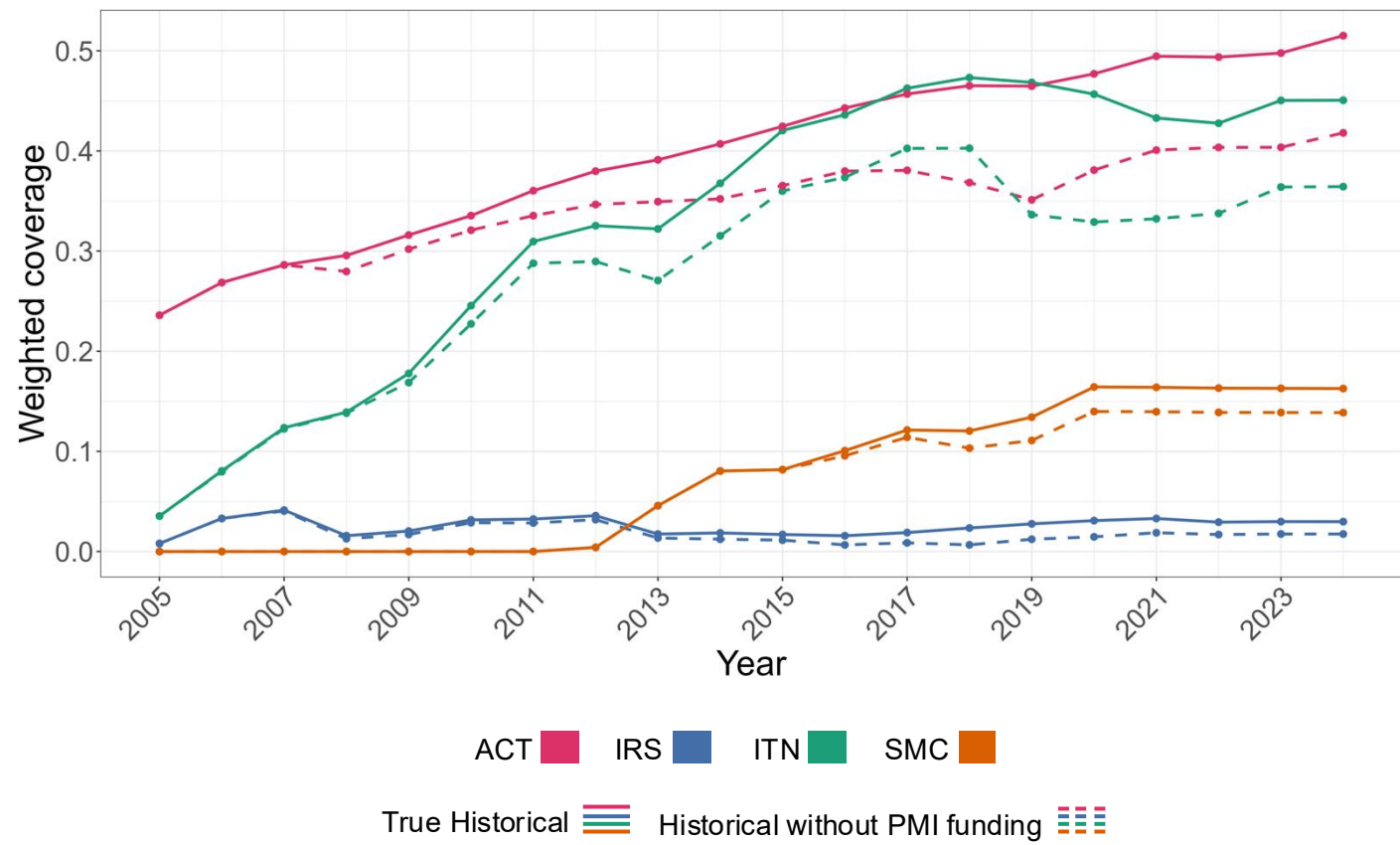
Independent analysis by two different modelling groups align on PMI's impact in SSA

- Two independent modelling groups, using **distinct modelling frameworks** and a shared data foundation, reproduced historical malaria incidence and mortality trends with and without PMI support, **converging on a similar magnitude of PMI's impact.**
- This ensemble approach demonstrates the **analysis is robust to different structural assumptions and inference approaches**, increasing confidence that the conclusions reflect real epidemiological signals.

# 1

## PMI's activities have facilitated widespread delivery of core malaria interventions (ITNs, SMC, IRS, and ACTs) across diverse settings

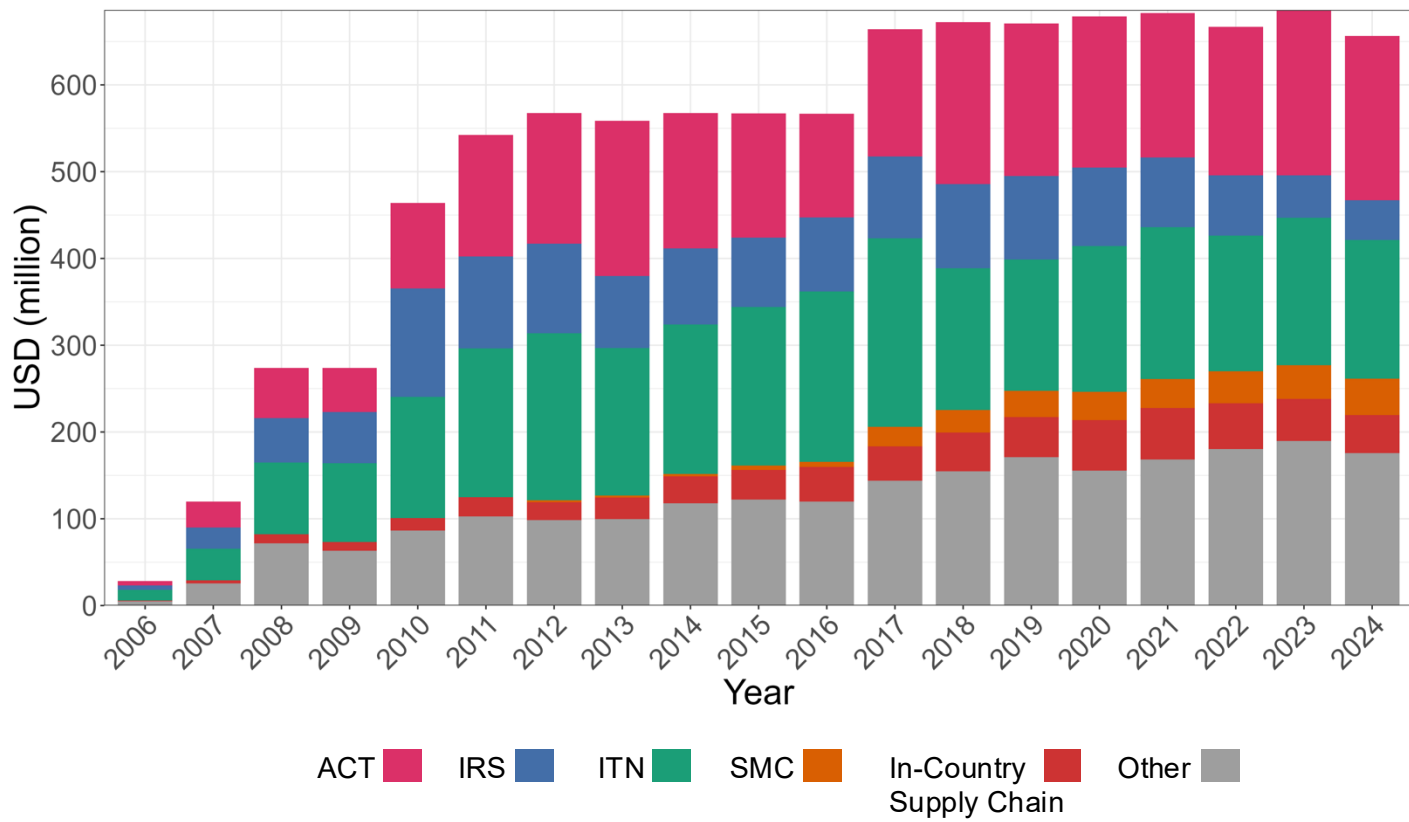
- Between 2005-2024, the combined efforts of international and domestic donors and health agencies led to **pronounced scale up in four key classes of malaria interventions** in the 25 countries studied, with PMI contributions crucial to this success.
- Over this period **PMI's proportional contribution to improvements in malaria intervention coverage was largest for indoor residual spraying**, at 43.3% for IRS, followed by ACTs (32.7%), ITNs (18%), and SMC (11.4%).
- The largest proportional PMI contributions to overall intervention coverage occurred in the period **2018-2020** reaching **72% for IRS**, **28% for ITNs**, **24% for ACTs**, and **17% for SMC**.



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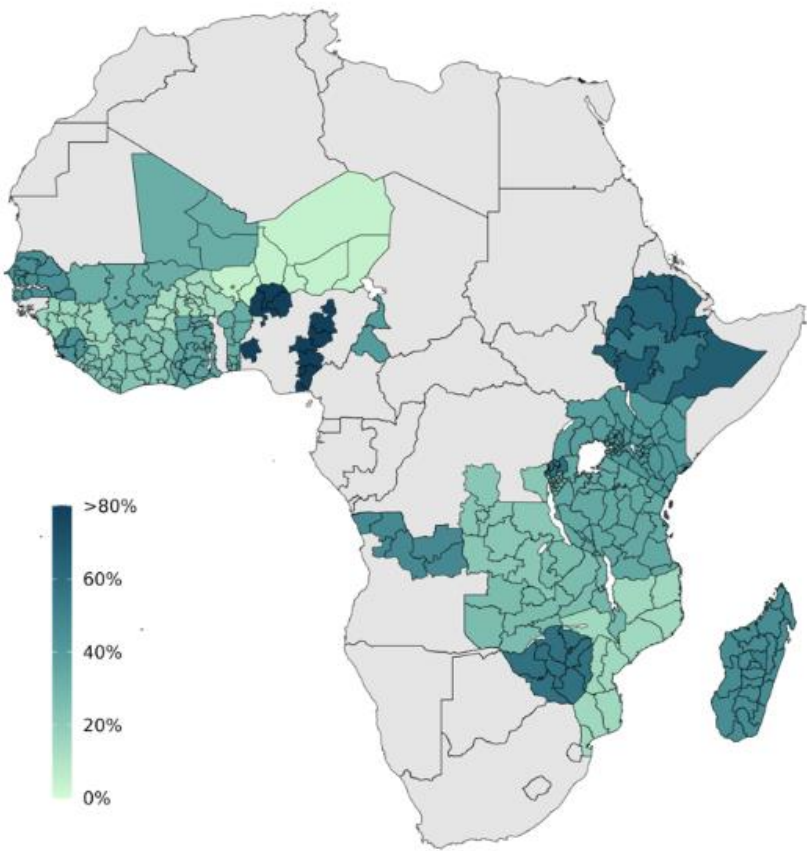
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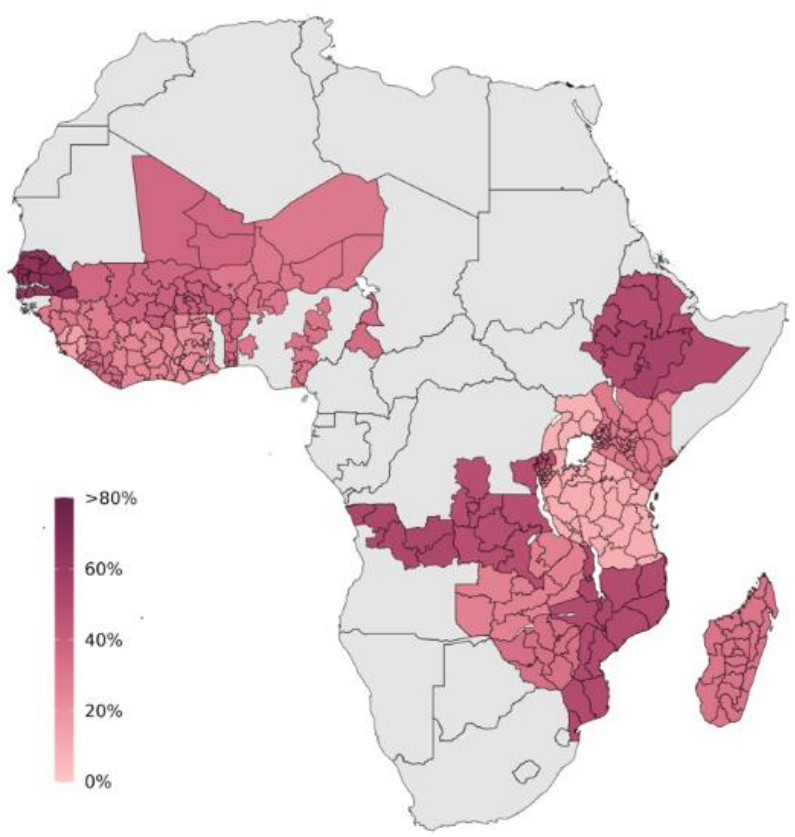
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# PMI's activities have facilitated widespread delivery of core malaria interventions (ITNs, SMC, IRS, and ACTs) across diverse settings

Mean proportion of ITN usage attributed to PMI



Mean proportion of antimalarial treatment coverage attributed to PMI



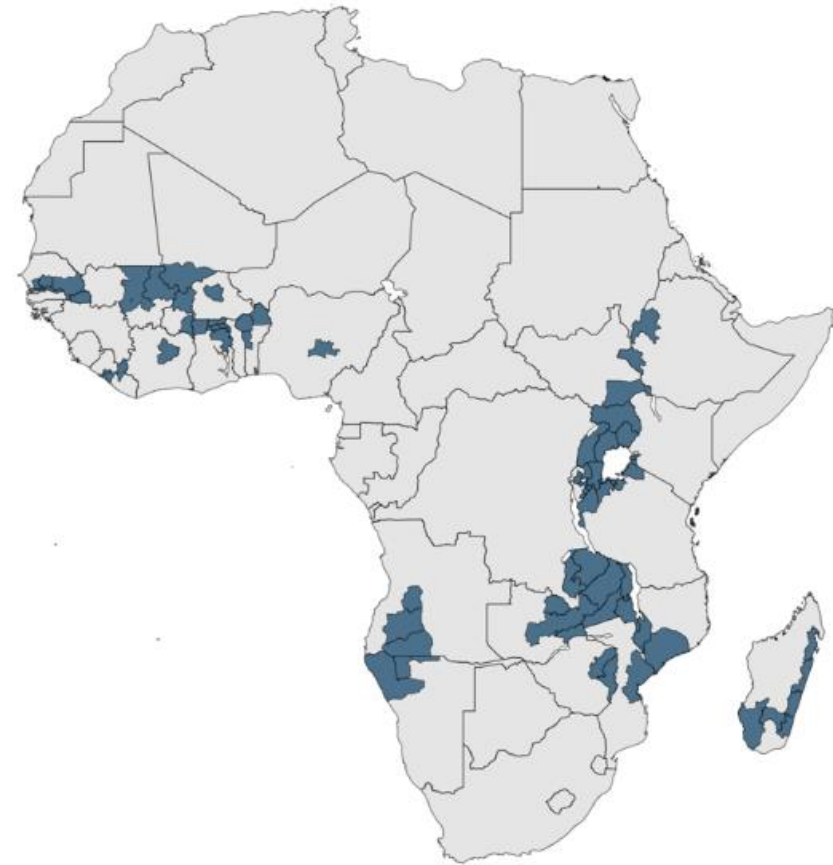
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# PMI's activities have facilitated widespread delivery of core malaria interventions (ITNs, SMC, IRS, and ACTs) across diverse settings

Areas where PMI has supported SMC



Areas where PMI has supported IRS

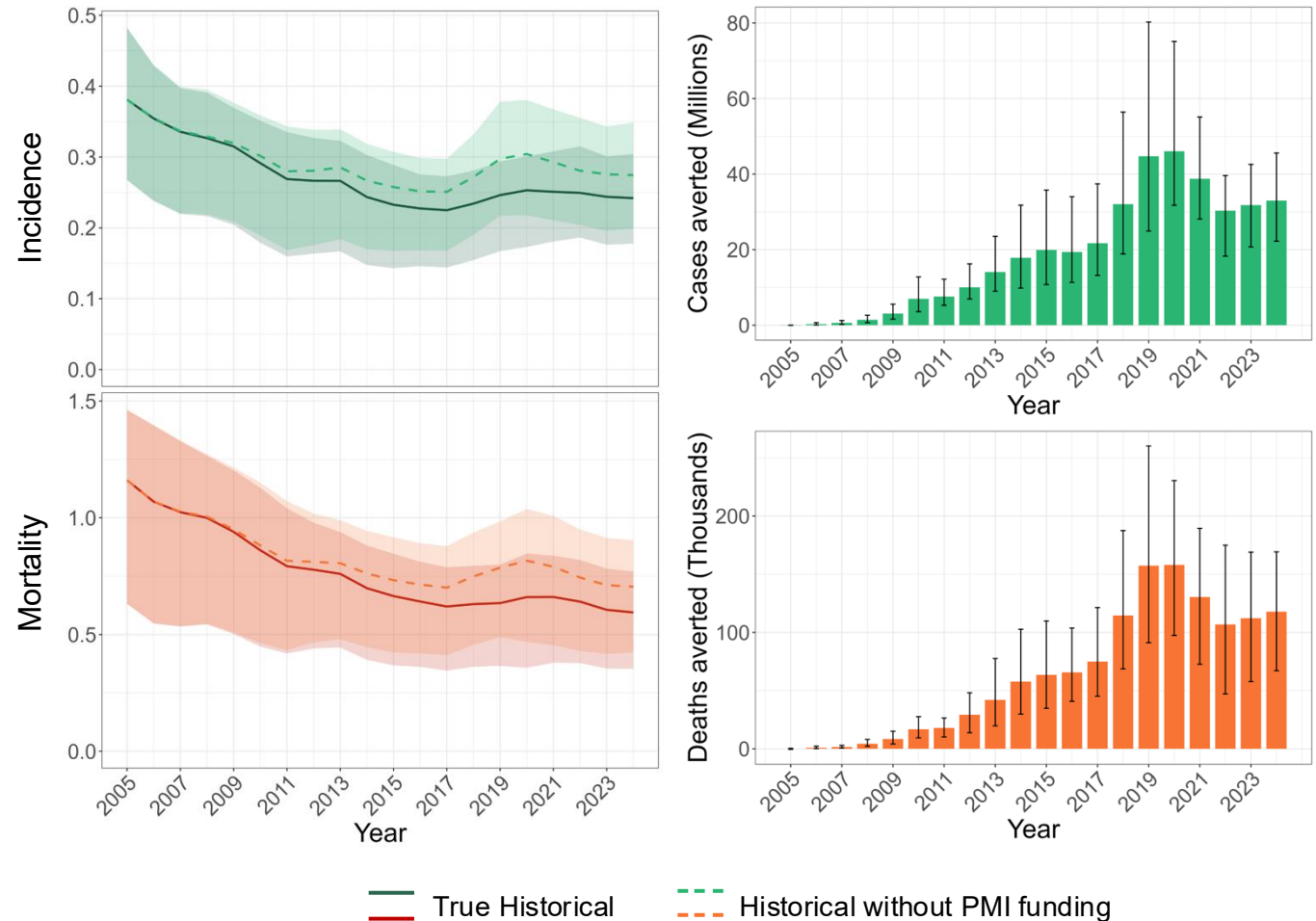


## 2

# PMI has contributed substantially to reductions in malaria transmission and mortality across partner countries.

- Malaria incidence and mortality declined in SSA between 2005-2024 reflecting sustained investments in malaria control by national governments and global partners.
- In 2024, the **incidence rate was 11.8% less** and the **mortality rate was 15.7% less** than a no-PMI scenario due to PMI contributions to malaria prevention (ITN, IRS, SMC) and case management (ACT).
- These activities are responsible for an estimated **reduction of 379 million cases** and **1.1 million deaths over the period**.
- Only **direct intervention impacts** were modelled; broader system investments (e.g. surveillance, M&E, programme strengthening) and their downstream benefits are not captured.

### Ensemble estimates of PMI impact

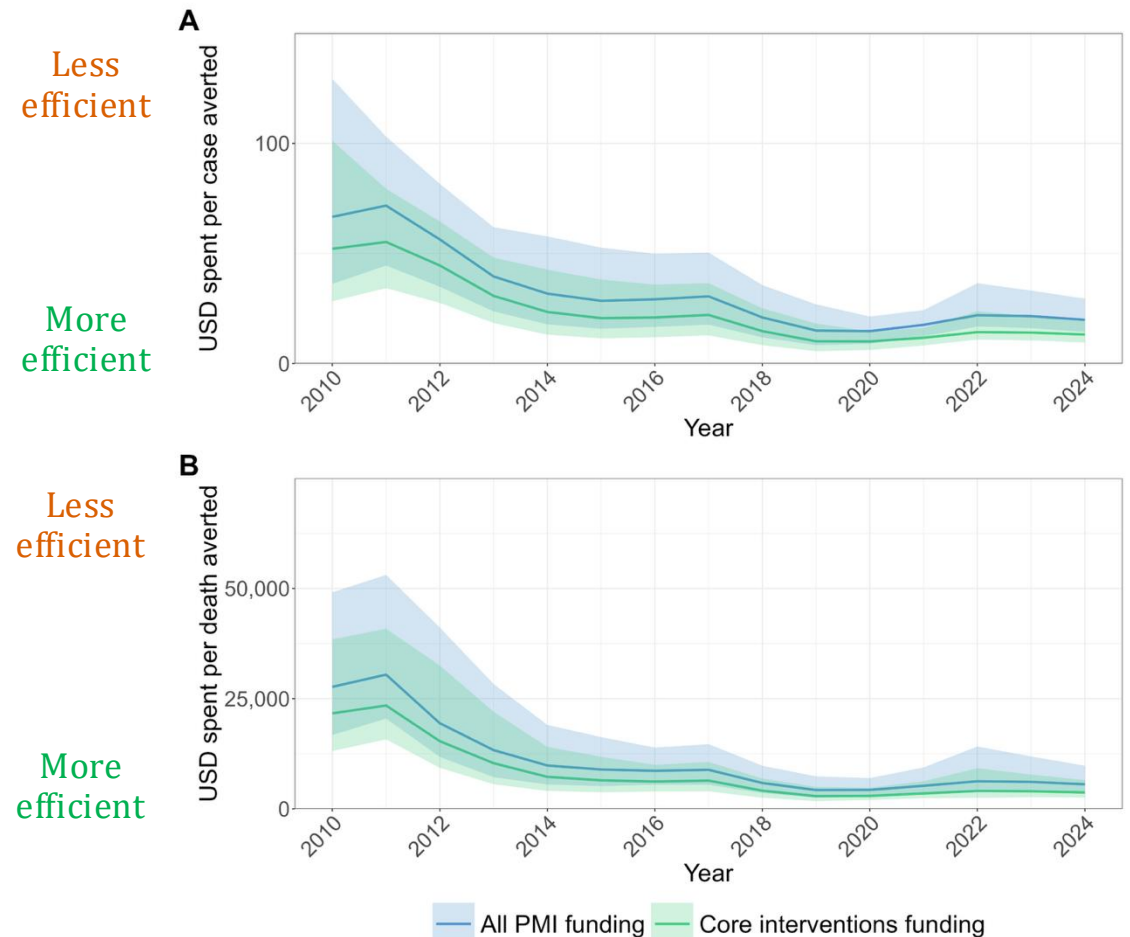


## 2

# PMI has contributed substantially to reductions in malaria transmission and mortality across partner countries.

- After initial scale-up, PMI efficiency improved substantially and has continued to increase over time, with cost per case and death averted remaining at low, stable levels.
- Annually, 2017-2024:
  - **Core interventions funding (ACT, IRS, ITNs, SMC)**  
USD did not exceed **\$23 per case averted** and **\$6,500 per death averted** in any given year.
  - **All PMI funding**  
USD did not exceed **\$31 per case averted** and **\$8,900 per death averted** in any given year.
- On average, across all years of PMI operation:
  - **Core interventions funding (ACT, IRS, ITNs, SMC)**  
PMI invested **\$18.6** (95% CrI \$11.6, \$25.8) **per case averted** and **\$6,205** (95% CrI \$4,587, \$9,848) **per death averted**.
  - **All PMI funding**  
PMI invested **\$26.2** (95% CrI \$16.3, \$36.3) **per case averted** and **\$8,718** (95% CrI \$6,444, \$13,836) **per death averted**.

PMI dollar spent per case/death averted

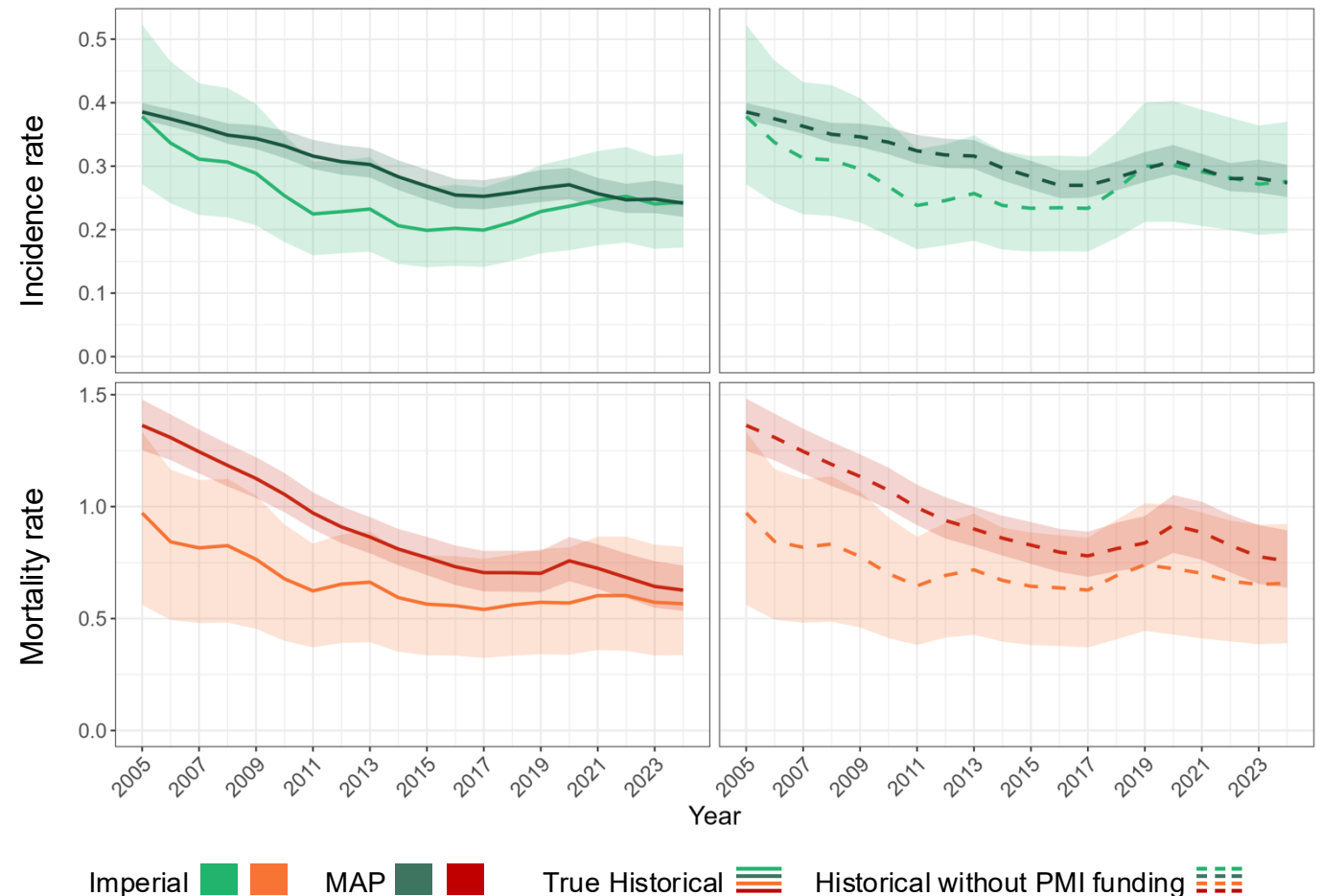


## 3

# Independent analysis by two different modelling groups align on PMI's impact in SSA

- Despite conceptually different modelling approaches (Imperial: transmission-dynamic; MAP: geospatial), both models **independently reproduced historical incidence and mortality trends**.
- When simulating historical trends both with and without PMI coverage, the estimated **uncertainty ranges overlap** and the **direction of change over time is consistent** across models.
- This convergence provides qualitative agreement on the estimated impact of PMI activities and increases **confidence that the conclusions reflect underlying epidemiological signals** rather than artefacts of any single modelling framework.

Trends in incidence & mortality disaggregated by modelling group



# 3

## Independent analysis by two different modelling groups align on PMI's impact in SSA

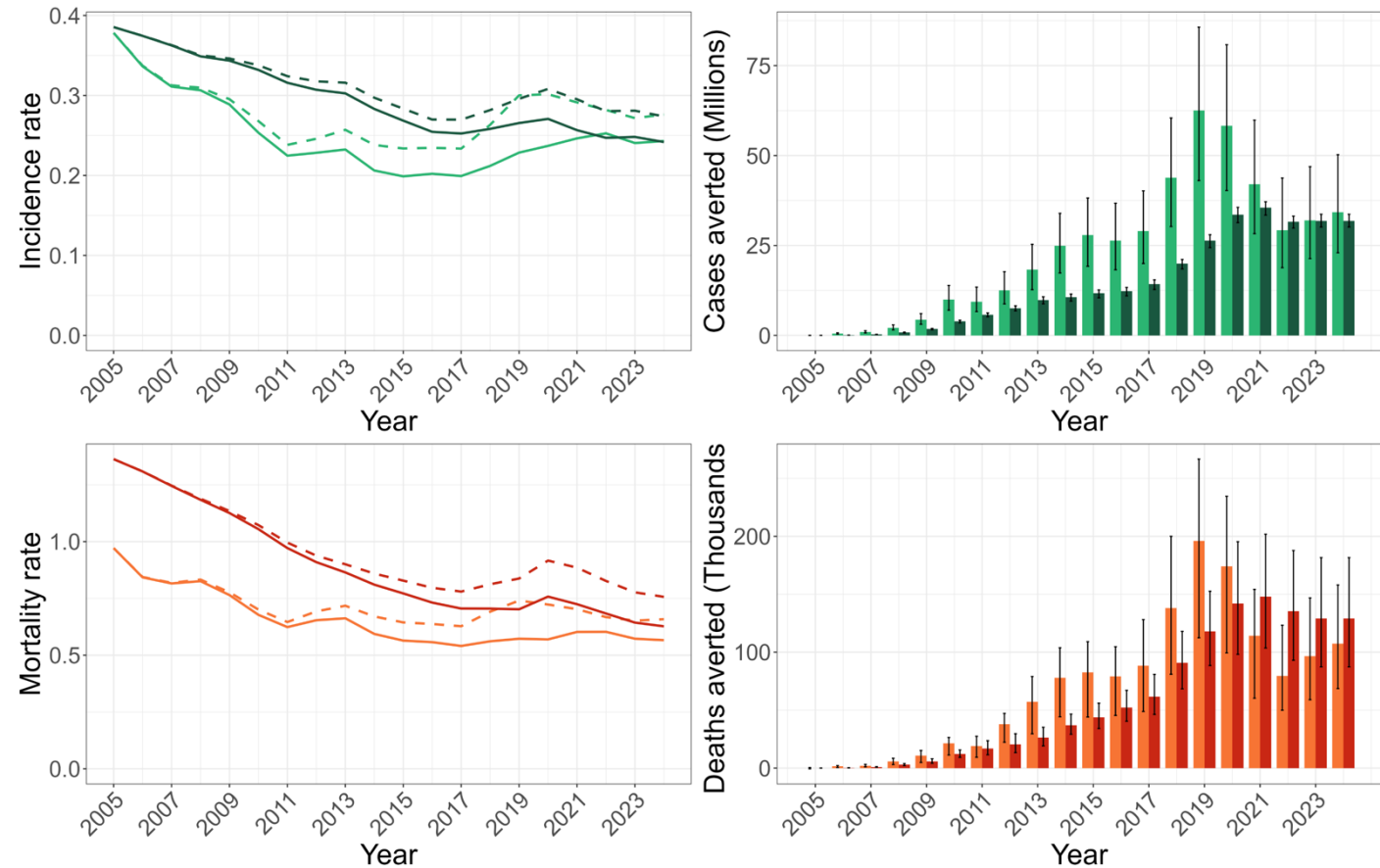
### Cases averted (millions):

- Imperial: 467 (321, 658)
- MAP: 290 (270, 310)

### Deaths averted (thousands):

- Imperial: 1107 (631, 1486)
- MAP: 1170 (890, 1620)

Estimates of PMI impact disaggregated by modelling group

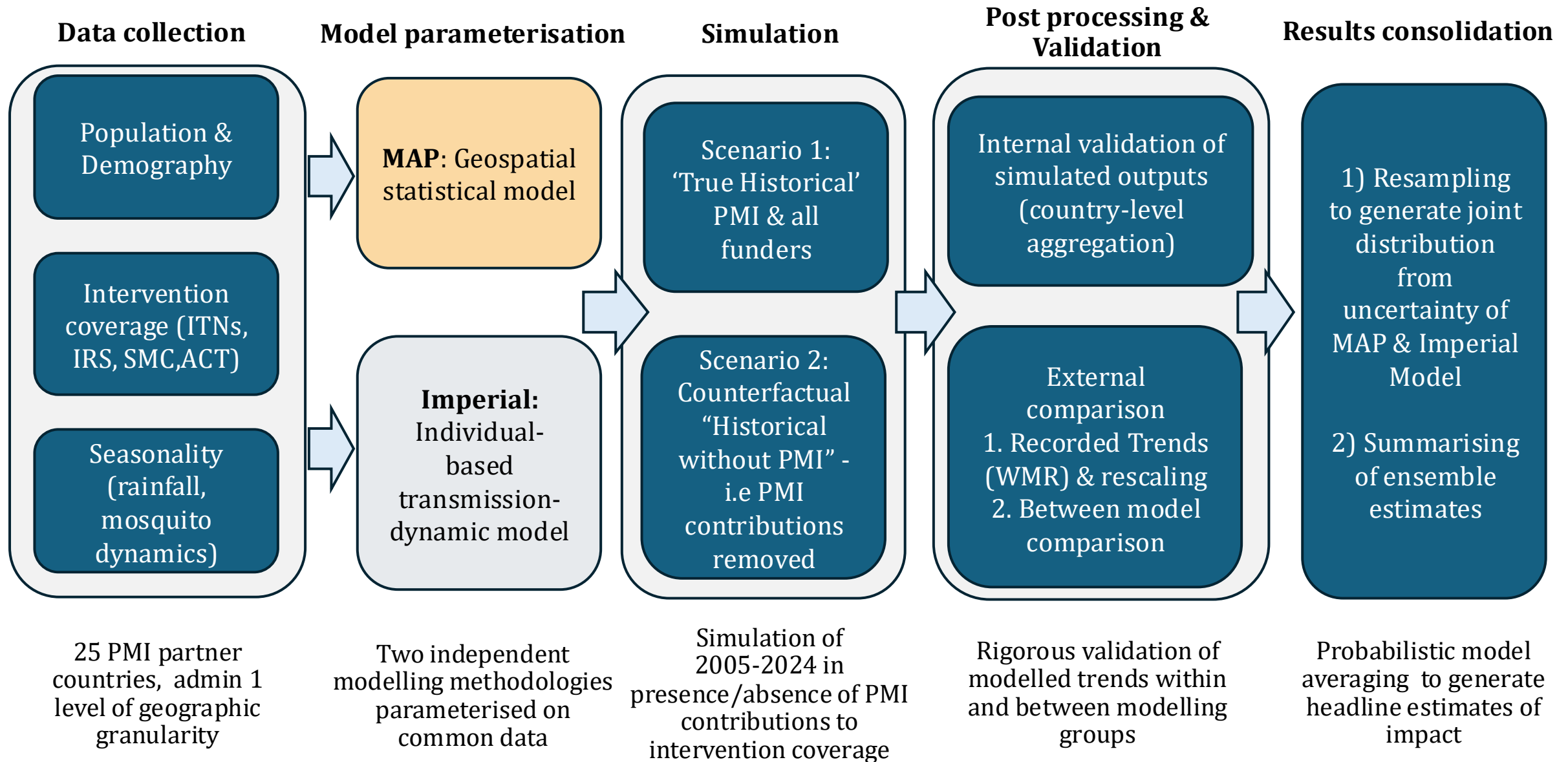


Imperial █ MAP █ True Historical █ Historical without PMI funding █

# Methods



# Methods Summary



# Methods – Mathematical modelling methodologies

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Two distinct modelling frameworks were applied independently, with alignment on intervention coverage and PMI contribution. Differences in model structure, assumptions, parameterisation, and data processing were intentionally preserved, reflecting real-world policy use of these models.

## **Imperial: 'malariasimulation'**

- Stochastic individual-based transmission-dynamic model of *Plasmodium falciparum* malaria with both human and mosquito components.
- Stratification by age and exposure, with transitions between key infection states (e.g. susceptible, infected, diseased, treated).
- Explicit representation of naturally acquired immunity, accumulated with exposure (EIR), reducing susceptibility to infection and progression to clinical disease.
- Bayesian fitting to age-stratified prevalence and incidence data under endemic equilibrium to characterise prevalence–disease relationships.

## **MAP: Geospatial Model**

- Bayesian geospatial model of *Plasmodium falciparum* parasite rate.
- Spatio-temporal interpolation of N=60K cross-sectional observations of *PfPR*.
- Intervention and environmental effects are estimated empirically within the Bayesian framework.
- Conversion of posterior *PfPR* predictions to age-stratified estimates of clinical incidence based on ensemble of transmission-dynamic models.
- Estimated malaria mortality derived from modelled untreated clinical cases and untreated case fatality rates.

# Methods – **Attributing PMI impact**

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- **Primary outcomes: malaria cases and deaths averted** - calculated by comparing modelled outcomes in scenarios with and without interventions (ITNs, SMC, IRS, ACT) for each at the admin 1 unit level and aggregating across geographies.
- Each modelling group attributed impact differently:

## **Imperial: Direct attribution**

Estimates the **marginal impact of PMI funding** by simulating outcomes with and without **PMI-supported intervention coverage**, holding all other funding sources constant.

## **MAP: Proportional attribution**

Estimates **total intervention impact** across all funders and **attributes a PMI share based on its proportion of total financing**, reflecting impact within a shared funding landscape.

- Results reflect heterogeneity in transmission intensity, intervention exposure, and population immunity over time across local settings.
- **Scope limitation:** Impacts of PMI activities on health-system strengthening and surveillance are not included.

# Methods – Probabilistic consolidation of impact estimates and accounting for uncertainty

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Results incorporate uncertainty from both parameter inference and differences in model structure.

- **Within-model uncertainty (parametric):**

- **Imperial:** Each scenario was simulated multiple times using parameter sets sampled from posterior distributions obtained during model calibration ( $n = 20$ ). This produced  $n$  time series per scenario, from which malaria cases and deaths were derived.
  - Outcomes reported as **medians with 95% credible intervals**.
- **MAP:** The geospatial model yields posterior distributions of malaria cases and deaths; multiple samples were drawn from these distributions ( $n = 100$ ), producing  $n$  sets of results per scenario.
  - Outcomes reported as **means with 95% confidence intervals**.

- **Between-model uncertainty (structural):**

Outputs from both models were combined using Bayesian model averaging and Bootstrap resampling:

- **Ensemble construction:** For each outcome and time point, samples were randomly drawn from model-specific uncertainty distributions (approximated from central estimates and 95% intervals) producing an ensemble distribution.
- **Final estimates:** Ensemble medians and 95% intervals reflect both parametric uncertainty within models and structural uncertainty between modelling frameworks.

# Estimating the impact of PMI's malaria control activities, 2005-2024

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# Appendix



# Appendix – SSA countries included in analysis

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Angola, Burundi, Benin, Burkina Faso, Côte d'Ivoire, Cameroon, Democratic Republic of Congo, Ethiopia, Ghana, Guinea, Kenya, Liberia, Madagascar, Mali, Mozambique, Malawi, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Tanzania, Uganda, Zambia, Zimbabwe.

Full details on the geographically specific data types and sources used for model parameterisation can be found in the accompanying supplementary report document.

# Appendix – Cumulative impact estimates: ensemble and disaggregated by modelling group

Cases					
Averted (Millions)			Averted per thousand PAR		
Imperial	MAP	Ensemble	Imperial	MAP	Ensemble
466.6 (320.5, 658.1)	289.4 (270.9, 307.4)	378.8 (272.9, 606.7)	601.3 (413, 847.9)	372.9 (349.1, 396.2)	488.1 (351.6, 781.8)

Deaths					
Averted (Thousands)			Averted per thousand PAR		
Imperial	MAP	Ensemble	Imperial	MAP	Ensemble
1107.2 (630.9, 1486.4)	1172.5 (893.3, 1615)	1136.5 (716.1, 1537.6)	1.4 (0.8, 1.9)	1.5 (1.2, 2.1)	1.5 (0.9, 2)

# Appendix – Annual cases & deaths averted – ensemble estimates

Metric	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Cases	Millions	0 (0, 0)	0.3 (0.1, 0.7)	0.6 (0.2, 1.2)	1.4 (0.7, 2.7)	3.1 (1.6, 5.6)	7 (3.6, 12.8)	7.6 (5.3, 12.2)	10.1 (7, 16.2)	14.1 (9, 23.5)	17.9 (9.8, 31.8)
Deaths	Thousand	0 (-0.4, 0.4)	0.9 (0.2, 2.2)	1.5 (0.7, 2.9)	4.4 (2.2, 8.1)	8.3 (4.2, 15.1)	16.8 (9.4, 27.7)	17.8 (10.2, 26.5)	29.2 (13.8, 48.1)	41.9 (19.7, 77.6)	57.7 (29.8, 102.7)

Metric	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Cases	Millions	19.9 (10.8, 35.8)	19.4 (11.4, 34)	21.7 (13.2, 37.4)	32.1 (18.9, 56.4)	44.7 (24.9, 80.2)	46.1 (31.8, 75.1)	38.8 (28.1, 55.1)	30.3 (18.3, 39.6)	31.8 (20.7, 42.6)	33 (22.2, 45.6)
Deaths	Thousand	63.5 (34.8, 109.7)	65.7 (40.8, 103.7)	75 (45.2, 121.3)	114.6 (68.7, 187.5)	157.4 (91.2, 260.1)	158.1 (97.4, 230.3)	130.4 (72.7, 189.4)	106.7 (47.2, 174.9)	112.3 (57.7, 168.9)	117.8 (67.1, 169.2)

# Appendix – Annual cases & deaths averted per thousand PAR- ensemble estimates

Metric	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Cases	Per thousand PAR	0 (0, 0)	0.5 (0.1, 1.1)	1 (0.4, 2)	2.3 (1.1, 4.2)	4.7 (2.5, 8.5)	10.3 (5.3, 19)	10.9 (7.6, 17.5)	14.1 (9.7, 22.7)	19.2 (12.3, 32)	23.6 (13, 42)
Deaths		0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0)	0 (0, 0.1)	0.1 (0, 0.1)

Metric	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Cases	Per thousand PAR	25.6 (13.8, 46)	24.2 (14.2, 42.5)	26.4 (16, 45.4)	37.8 (22.2, 66.5)	51.3 (28.6, 92)	51.4 (35.4, 83.8)	42.1 (30.5, 59.9)	32.1 (19.4, 41.9)	32.8 (21.4, 43.9)	33.1 (22.3, 45.8)
Deaths		0.1 (0, 0.1)	0.1 (0.1, 0.1)	0.1 (0.1, 0.1)	0.1 (0.1, 0.2)	0.2 (0.1, 0.3)	0.2 (0.1, 0.3)	0.1 (0.1, 0.2)	0.1 (0, 0.2)	0.1 (0.1, 0.2)	0.1 (0.1, 0.2)

# Appendix – Annual weighted intervention coverage all funding vs all funding & no PMI

Intervention	Metric	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
ITN	Coverage	0.035	0.081	0.124	0.139	0.178	0.246	0.310	0.325	0.322	0.368
	Coverage with no PMI	0.035	0.080	0.123	0.138	0.169	0.227	0.288	0.290	0.271	0.315
SMC	Coverage	0	0	0	0	0	0	0	0.004	0.046	0.080
	Coverage with no PMI	0	0	0	0	0	0	0	0.004	0.046	0.080
IRS	Coverage	0.008	0.033	0.041	0.016	0.02	0.032	0.032	0.036	0.017	0.019
	Coverage with no PMI	0.008	0.033	0.04	0.013	0.017	0.029	0.029	0.032	0.013	0.012
ACT	Coverage	0.236	0.269	0.286	0.296	0.316	0.335	0.360	0.380	0.391	0.407
	Coverage with no PMI	0.236	0.269	0.286	0.280	0.302	0.321	0.335	0.347	0.349	0.352

Intervention	Metric	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
ITN	Coverage	0.42	0.436	0.463	0.473	0.468	0.457	0.433	0.428	0.450	0.451
	Coverage with no PMI	0.36	0.374	0.403	0.403	0.336	0.329	0.332	0.338	0.364	0.364
SMC	Coverage	0.082	0.101	0.121	0.120	0.134	0.164	0.164	0.163	0.163	0.163
	Coverage with no PMI	0.082	0.096	0.114	0.103	0.111	0.14	0.14	0.139	0.139	0.139
IRS	Coverage	0.017	0.016	0.019	0.023	0.028	0.031	0.033	0.029	0.03	0.030
	Coverage with no PMI	0.011	0.007	0.009	0.007	0.012	0.015	0.019	0.017	0.017	0.017
ACT	Coverage	0.425	0.443	0.457	0.465	0.465	0.477	0.495	0.494	0.498	0.515
	Coverage with no PMI	0.365	0.38	0.381	0.368	0.351	0.381	0.401	0.404	0.404	0.418

# Appendix – Annual percentage PMI contribution to intervention coverage

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Intervention	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
ITN	0	1.1	0.9	0.7	5.1	7.4	7	11	16	14.3
SMC	-	-	-	-	-	-	-	0	0	0
IRS	0	0	2.2	19.1	16.6	8.9	12.1	11	22.6	33.6
ACT	0	0	0	5.4	4.5	4.3	6.9	8.8	10.7	13.5

Intervention	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
ITN	14.4	14.3	13	14.9	28.2	28	23.2	21.1	19.2	19.1
SMC	0	0	5.1	6	14.3	17.3	14.9	14.9	14.9	14.8
IRS	33	57.9	54.1	71.7	55.6	52.5	43.2	42.2	41.5	41.5
ACT	13.9	14.2	16.7	20.8	24.4	20.2	19	18.3	18.9	18.8

# Appendix – Overall percentage PMI contribution to increases in and to total intervention coverages (2005-2024)

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Intervention	Percentage PMI contribution relative to	
	Total intervention coverage	Improvements in intervention coverage
ITN	16.1	18.0
SMC	11.4	11.4
IRS	29.9	43.3
ACT	13.5	32.7

# Appendix – PMI cumulative spending and investment efficiency. Ensemble & disaggregated by modelling group

Funding	USD	USD spent per case averted			USD spent per death averted		
		Imperial	MAP	Ensemble	Imperial	MAP	Ensemble
All PMI funding	9,908,629,974	21.2 (15.1, 30.9)	34.2 (32.2, 36.6)	26.2 (16.3, 36.3)	8949 (6666, 15706)	8,451 (6,135, 11,092)	8718 (6444, 13836)
Core intervention funding	7,052,370,433	15.1 (10.7, 22)	24.4 (22.9, 26.0)	18.6 (11.6, 25.8)	6369 (4744, 11179)	6015 (4,367, 7,895)	6205 (4587, 9848)