Malaria Campaign Impact Calculator Statistical Methods

This document describes the statistical methodology for the calculations performed by the Malaria Campaign Impact Calculator.

1. Estimating reductions in malaria mortality

For each age category j, we calculate "lives saved" as the difference in the expected number of malaria deaths before and after the campaign.

$$\text{Lives saved}_j = \text{Malaria deaths}_{j,\text{ before}} - \text{Malaria deaths}_{j,\text{ after}}$$

We take the number of malaria deaths *before* the campaign from an existing source as an input parameter for the model. This number is itself difficult to estimate and may also be estimated through modeling. The number can be estimated directly, or calculated as a product of the total number of deaths in age category j and the proportion of mortality in age cateogry j due to malaria. The default values for baseline malaria mortality in the tool come from the World Malaria Report.

We can say that the number of malaria deaths is a function of the total mortality risk reduction (TMRR) and the expected number of malaria deaths in the absence of any risk reduction. Although we don't know the expected number of malaria deaths in the absence of any risk reduction, we can use this relationship to estimate malaria deaths *after* a campaign, from the estimated malaria deaths *before* a campaign, and the *before* and *after* risk reductions, as follows:

$$\text{Malaria deaths} = \text{Malaria deaths in the absence of any risk reduction} \times (1 - \text{TMRR})$$

$$\text{Malaria deaths}_{\text{after}} = \text{Malaria deaths}_{\text{before}} \times \left(\frac{1 - \text{TMRR}_{\text{after}}}{1 - \text{TMRR}_{\text{before}}} \right)$$

We calculate TMRR for age category j as the mean of the individual mortality risk reduction (IMRR) for each person i in that age cateogry.

$$\begin{aligned} \text{TMRR}_j &= \text{Total mortality risk reduction for age category } j \\ &= \frac{1}{n_j} \sum_{i=1}^{n_j} \text{IMRR}_{i,j} \end{aligned}$$

We assume that the risk reductions due to ITN and SMC are independent, with SMC acting on the residual deaths remaining after the preventative effects of ITN use.

$$\begin{aligned}\text{IMRR}_{i,j} &= \text{Individual mortality risk reduction for person } i \text{ in age category } j \\ &= 1 - ((1 - \text{IMRR}_{\text{ITN},\, i,\, j}) \times (1 - \text{IMRR}_{\text{SMC},\, i,\, j}))\end{aligned}$$

$$\text{IMRR}_{\text{ITN}} = \text{Individual mortality risk reduction due to ITN coverage}$$

$$\text{IMRR}_{\text{SMC}} = \text{Individual mortality risk reduction due to SMC coverage}$$

2. Estimating reductions in malaria incidence

We use the same approach to estimate reductions in incidence as we do to estimate reductions in mortality, described above.

$$\text{Incidence}_{\text{ after}} = \text{Incidence}_{\text{ before}} \times \left(\frac{1 - \text{TIRR}_{\text{ after}}}{1 - \text{TIRR}_{\text{ before}}}\right)$$

$$\begin{aligned}\text{TIRR}_{j} &= \text{Total incidence risk reduction for age category } j \\ &= \frac{1}{n_j} \sum_{i=1}^{n_j} \text{IIRR}_{i,j}\end{aligned}$$

$$\begin{aligned}\text{IIRR}_{i,j} &= \text{Individual incidence risk reduction for person } i \text{ in age category } j \\ &= 1 - ((1 - \text{IIRR}_{\text{ITN},\, i,\, j}) \times (1 - \text{IIRR}_{\text{SMC},\, i,\, j}))\end{aligned}$$

$$\text{IIRR}_{\text{ITN}} = \text{Individual incidence risk reduction due to ITN coverage}$$

$$\text{IIRR}_{\text{SMC}} = \text{Individual incidence risk reduction due to SMC coverage}$$

3. Risk reduction due to ITN coverage

We calculate the risk reduction due to ITN coverage on *mortality* and *incidence* in the same way. The only difference is that we use different values for the effectiveness of ITN coverage on mortality versus incidence. For example, the tool uses a default value of 55% for the effectiveness of ITN use on malaria mortality, and a default value of 45% for the effectiveness of ITN use on malaria incidence.

$$\begin{aligned}\text{IMRR}_{\text{ITN},\, i,\, j} &= \text{Individual mortality risk reduction for person } i \text{ in age category } j \\ &= \text{Coverage}_{i,j} \times \text{Effectiveness of ITN coverage on mortality}_j\end{aligned}$$

$$\begin{aligned}\text{IIRR}_{\text{ITN},\, i,\, j} &= \text{Individual incidence risk reduction for person } i \text{ in age category } j \\ &= \text{Coverage}_{i,j} \times \text{Effectiveness of ITN coverage on incidence}_j\end{aligned}$$

In order to calculate ITN coverage for each individual person (i.e. whether the person does or does not sleep under a bednet), we consider two probabilities: the probability that a person has access to a bednet, and the probability that a person uses a bednet if they have access to it.

$$\text{Coverage}_{i,j} \in \begin{cases} 0 & \text{Person does not sleep under a bednet} \\ 1 & \text{Person sleeps under a bednet} \end{cases}$$

$$\Pr(\text{Coverage}_{i,j} = 1) = \Pr(\text{Access})_h \times \Pr(\text{Use} \mid \text{Access})_j$$

Estimating ITN access

We estimate changes in ITN access as a function of the total number of bednets in circulation. We hold population size constant, because we are comparing the immediate before-after change over the lifetime of a campaign, which is short (weeks or months).

We assume that the probability of access to a bednet is equal across household members. While we do not think this affects *changes* in access, this is nonetheless a limitation that should be corrected in future models.

For each household h, we calculate the probability of an individual person having access to a bednet. We assume that this probability is the same for every person i in household h. This is another potential limitation of the model, as it may be the case that household members in some age categories are given preferential access to bednets if there are fewer bednets than needed in a household.

$$\Pr(\text{Access})_h = \begin{cases} (\text{NB}_h \times 2)/\text{NP}_h & \text{if } (\text{NB}_h \times 2) < \text{NP}_h \\ 1 & \text{if } (\text{NB}_h \times 2) \geq \text{NP}_h \end{cases}$$

$$\begin{aligned} \text{NB}_h &= \text{Number of bednets in household } h \\ &= \begin{cases} \text{Any}_h \times \text{ceil}(\text{NP}_h/2) & \text{if } \text{NP}_h < (\text{MaxB} \times 2) \\ \text{Any}_h \times \text{MaxB} & \text{if } \text{NP}_h \geq (\text{MaxB} \times 2) \end{cases} \end{aligned}$$

$$\text{NP}_h = \text{Number of people in household } h$$

$$\text{MaxB} = \text{Maximum number of bednets distributed to a single household}$$

$$\text{Any}_h \in \begin{cases} 0 & \text{Household has no bednets} \\ 1 & \text{Household has at least one bednet} \end{cases}$$

We estimate the probability that each household h has at least one bednet *before* and *after* the ITN campaign. For the "before" value, we use the percentage of households with at least one bednet, taken from a recent household survey (DHS or MIS). For the "after" value, we multiply the percentage of households registered for the ITN campaign by the percentage of registered households that redeem their bednets. The percentage of households registered for the ITN campaign will likely need to be assumed, based on the expectations of the campaign of reaching a certain proportion of households in the country or sub-national area. The percentage of registered households that redeem their bednets should come from program records.

$$\Pr(\text{Any}_h = 1)_{\text{before}} = \%\ \text{HHs with at least one bednet}$$

$$\Pr(\text{Any}_h = 1)_{\text{after}} = \%\ \text{HHs registered} \times \%\ \text{Registered HHs that redeem their bednets}$$

Estimating ITN use

In order to calculate ITN coverage for a person, we need the probability that the person will actually sleep under a bednet if they have access to a bednet. We assume that this probability may be different before and after a campaign, so we allow users of the tool to enter both a before and after value. The "before" value could be taken from a recent household survey (DHS or MIS). The "after" value could be hypothesized by the user, to account for an assumed increase in ITN use following the campaign, or it could be considered to remain constant and be the same as the "before" value.

$$\begin{aligned}\Pr(\text{Use} \mid \text{Access})_{j,\text{ before}} &= \text{Proportion of people in age category } j \text{ who sleep under a bednet,}\\ &\quad\ \text{among those with access to a bednet}\end{aligned}$$

$$\begin{aligned}\Pr(\text{Use} \mid \text{Access})_{j,\text{ after}} &= \text{Proportion of people in age category } j \text{ who sleep under a bednet,}\\ &\quad\ \text{among those with access to a bednet}\end{aligned}$$

4. Risk reduction due to SMC coverage

Currently, SMC is only administered to children, and the scientific literature only offers evidence for an effect of SMC on malaria incidence and mortality in children. Thus for non-children age categories, we assume no coverage and therefore no risk reduction from SMC coverage.

For children, we calculate the risk reduction due to SMC coverage on *mortality* and *incidence* in the same way. The only difference is that we use different values for the effectiveness of SMC coverage on mortality versus incidence. The tool uses a default value of 42.5% for the effectiveness of SMC on malaria mortality, and a default value of 45% for the effectiveness of SMC on malaria incidence.

$$\begin{aligned}\text{IMRR}_{\text{SMC},\, i} &= \text{Individual mortality risk reduction for child } i\\ &= \text{Coverage}_{i,j} \times \text{Effectiveness of SMC coverage on malaria mortality}\end{aligned}$$

$$\begin{aligned}\text{IIRR}_{\text{SMC},\, i} &= \text{Individual incidence risk reduction for child } i\\ &= \text{Coverage}_{i,j} \times \text{Effectiveness of SMC coverage on malaria incidence}\end{aligned}$$

We calculate SMC coverage for each child as the proportion of weeks of the high-risk malaria season for which they are covered by SMC. We assume that baseline coverage is always 0%, because an SMC campaign only reduces malaria risk for the season in which the campaign is implemented.

$$\text{Coverage}_i = \frac{\text{Weeks covered}_i}{\text{Weeks at risk}}$$

The number of "weeks at risk" is equivalent to the length of the high-risk malaria season (rainy period), in weeks, for the country or sub-national area. The default value for this in the tool is 16 weeks.

$$\text{Weeks at risk} = \text{Length of high-risk rainy season}$$

For each child i, we calculate their number of "weeks covered" as a function of the number of times they are treated with SMC. The maximum number of times that a child can be treated is equivalent to the number of "cycles" of the SMC campaign. Each time a child is treated, we assume they have 4 weeks of SMC coverage. Thus if a child is treated 4 times (i.e. in each of 4 cycles of a campagin), they will be covered for 16 weeks. If the length of the high-risk malaria season is also 16 weeks, this will mean that the child has 100% SMC coverage for that year. If another child is only treated 3 times, they will be covered for 12 weeks, and will therefore have 75% SMC coverage for that year.

$$\text{Weeks covered}_i = \sum_{c=1}^{\text{NC}} (\text{Treated}_{i,c} \times 4 \text{ weeks})$$

$$\begin{aligned}\text{NC} &= \text{Number of campaign cycles} \\ &\in \{0,1,2,3,4,5,6\}\end{aligned}$$

$$\text{Treated}_{i,c} \in \begin{cases} 0 & \text{Child does not receive SMC in cycle } c \\ 1 & \text{Child does receive SMC in cycle } c \end{cases}$$

We calculate the probability of each child i receiving SMC treatment in cycle c as the percentage of children in the country or sub-national area who are targeted by the SMC campaign, multiplied by the percentage of targeted children who do in fact receive treatment. The percentage of children targeted by the campaign will likely need to be assumed, based on the protocols or expectations of the campaign for reaching a certain proportion of children in the country or sub-national area. The percentage of targeted children who are treated should come from program records.

$$\Pr(\text{Treated}_{i,c} = 1) = \text{\% Children targeted} \times \text{\% Targeted children who are treated}_c$$