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Standards for Official Statistics on Climate-Health Interactions (SOSCHI)

Vector-borne diseases (malaria): introduction

Alpha Phase document

Publication date: 12 November 2024

We welcome users' views and expertise on the alpha version of the statistical framework to further develop our work. Please email us at climate.health@ons.gov.uk.

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Introduction to the SOSCHI project

The impacts on the health of rising temperatures, wildfires, extreme weather events, and other direct and indirect effects of climate change are a major global concern. The most significant hazards and their impacts differ between countries and regions, as do the possibilities and priorities for climate change adaptation. National and local governments and other stakeholders need to have regular, reliable, and comparable data to monitor climate impacts and inform adaptation strategies, based on a transparent and globally generalizable statistical framework. The SOSCHI project, led by the UK Office for National Statistics and funded by Wellcome, is developing a framework of indicators based on state-of-the-art statistical methods to measure climate-related health risks. We are also developing a knowledge-sharing platform, open-source tools, and R code to support global reporting and monitoring. Our findings will also help highlight data gaps and help set the agenda for future improvement of data sources and methods.

Project partners

African Institute for Mathematical Sciences Research and Innovation Centre, Kigali, Rwanda
Cochrane Planetary Health Thematic Group, University of Alberta, Edmonton, Canada
Office for National Statistics, Newport, United Kingdom
Regional Institute for Population Studies, University of Ghana, Accra, Ghana
UK Health Security Agency, London, United Kingdom
United Nations Global Platform, New York, United States of America

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Authors	Etse Yawo Dzakpa[1], Duah Dwomoh[2], Margaret Appiah[2], Mawuli Dzodzomenyo[2] [1]African Institute for Mathematical Sciences Research and Innovation Centre (AIMSRIC), Rwanda [2]Regional Institute for Population Studies (RIPS), University of Ghana, Legon
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Contact	Climate and Health Team, Health and International Division, Office for National Statistics, Newport NP10 8XG, United Kingdom Climate.health@ons.gov.uk AIMS-ONS Team, African Institute for Mathematical Sciences Research & Innovation Centre (AIMSRIC), District Gasabo, Secteur Kacyiru, Cellule Kamatamu, Rue KG590 ST 1. P.O Box: 6428, Kigali, Rwanda centrepresidentoffice@aimsric.org RIPS Team, Regional Institute for Population Studies, University of Ghana, Legon cchealth@rips-ug.edu.gh
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Important notes

This document has been published as part of the alpha version of the SOSCHI statistical framework. Therefore, this should be read as a draft document, which does not necessarily represent the final state of the framework. We welcome users' views and expertise to further develop our work.

Please email us at climate.health@ons.gov.uk

Abbreviations

A	AIMSRIC	African Institute for Mathematical Sciences Research and Innovation Centre
	AR6	Sixth-Assessment Report from IPCC
E	EHBM	Expanded Home-based Management of Malaria
F	FDES	Framework for the Development of Environment Statistics
I	ICD-10-CM	International Classification of Diseases, Tenth Revision, Clinical Modification
	IPCC	Intergovernmental Panel on Climate Change
N	NDVI	Normalized Difference Vegetation Index
O	ONS	Office for National Statistics (UK)
R	RIPS	Regional Institute for Population Studies, University of Ghana, Legon
S	SDGs	Sustainable Development Goals
	SOSCHI	Standards for Official Statistics on Climate-Health Interactions
	SPEI	Standardized Precipitation Evapotranspiration Index
	SPI	Standardized Precipitation Index
U	UK	United Kingdom of Great Britain and Northern Ireland
	UKHSA	United Kingdom Health Security Agency
	UN	United Nation
	UNDP	United Nations Development Programme
W	WHO	World Health Organization

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As part of upcoming beta phase developments, we are seeking expert feedback to support the development of this topic. Please contact: climate.health@ons.gov.uk if you would like to contribute to this work.

1. Vector-borne diseases: Malaria and Climate Change

1.1 Definition and Scope

Vector-borne diseases remain one of the deadly human illnesses caused by parasites, viruses, and bacteria transmitted by mosquitoes, sandflies, triatomine bugs, blackflies, ticks, tsetse flies, mites, and snails. It accounts for more than 17% of all infectious diseases, causing more than 700.000 deaths annually[1]. The most well-known vector-borne diseases include dengue, malaria, chikungunya, yellow fever, Rift Valley Fever, and Zika which are transmitted by mosquitoes; Lyme disease transmitted by ticks; African sleeping sickness from tsetse fly; and schistosomiasis from aquatic snails (WHO, 2020).

Malaria is a significant public health problem in most of the tropical and subtropical countries of the world[2,3]. Mainly caused by protozoan parasites of the genus Plasmodium, it is commonly transmitted between humans by infected female anopheles mosquitoes' bite. Numerous plasmodium species exist. Among them, the following are responsible for causing malaria: Plasmodium ovale, Plasmodium falciparum, Plasmodium malariae, Plasmodium vivax, and Plasmodium knowlesi. Globally, developing countries bear a disproportionately high share of the global malaria burden. According to the African Union Malaria Status Report, in 2022, 1.27 billion individuals were at risk of malaria infection in Africa. Amongst them, were 186 cases per 1,000 persons and 47 deaths per 100,000 persons (African Union Malaria Status Report 2022).

Among factors influencing malaria transmission such as demographic, meteorological, socio-economic factors, and human behaviors, the effect of climate change is widely recognized. The sixth-assessment report of the Intergovernmental Panel on Climate Change (AR6), reports with high confidence the correlation between climate change and likely increasing vector-borne diseases such as malaria, dengue, Lyme disease, and West Nile virus infection in particular[4,5]. Indeed, studies show that a rise in malaria infections is associated with moderate temperature, rainfall, and relative humidity. Its spread depends on a certain amount of rainfall and temperature changes[2,6]. Climate change exacerbates the impact of these climatic factors, creating optimal conditions for mosquito breeding and affecting the behavior and geographical distribution of malaria vectors[3,7].

Evidence shows that temperatures between 20°C and 30°C, are conducive to the development of the malaria parasite[6,7]. Thus, the increase of the temperature above the optimal range acts to speed up the rate of parasite development, while temperatures outside this range can inhibit mosquito survival and parasite development[8–10]. Moreover, due to temperature changes, low transmission rate areas may see an increase in transmission as rising temperatures reach the optimal level for vector breeding[2,10]. Most likely, higher air humidity levels tend to increase malaria transmission, and with climate change effects, areas where malaria is not common could also face an increased transmission due to elevated humidity[11].

Rainfall plays a crucial role in malaria transmission by providing breeding sites for mosquito development. However, the impact of rainfall on malaria is complex and depends on the amount, distribution, and intensity of rainfall[12]. Indeed, rainfall patterns are expected to alter significantly as climate change worsens with increasing regional variabilities, creating more favorable conditions for vector breeding. Increased malaria transmission is expected with increasing rainfall patterns and extension of malaria risk to new populations due to the expansion of the geographic range of malaria. However, heavy rainfall may also decrease the rate of malaria transmission by washing away mosquito vectors through disruption of breeding sites, reducing mosquito populations[2,8,10,12].

In addition to temperature, rainfall, and relative humidity, extreme weather events caused by climate change, such as droughts, floods, and waterlogging, may greatly affect the breeding and transmission of malaria vectors (World Malaria Report 2023). Flooding, which occurs as a result of prolonged and heavy rainfall, has the potential to wash away existing breeding sites for mosquitos, known as malaria vectors. However, new breeding grounds could be established in the numerous small pools of stagnant water left behind after the flood creating new hosts and abundant reservoirs for vector breeding. This, in turn, leads to a significant increase in malaria cases several months after the disaster occurrence[3,13,14].

Eliminating malaria by 2030 remains a top priority within the Sustainable Development Goals (SDGs). Referring to its target 3.3, it is set a net zero malaria case by 2030. However, the World Health Organization reports that climate change constitutes a major threat to health and the fight against malaria[3]. Also, the Intergovernmental Panel on Climate Change (IPCC) projected that the prevalence of malaria will continue increasing over the next 80 years if no action is taken to adapt and strengthen control strategies[5]. Therefore, studying the connection between climate change and malaria is crucial for enhancing current policies and interventions to achieve the SDGs target by 2030.

1.2 Impact Pathway

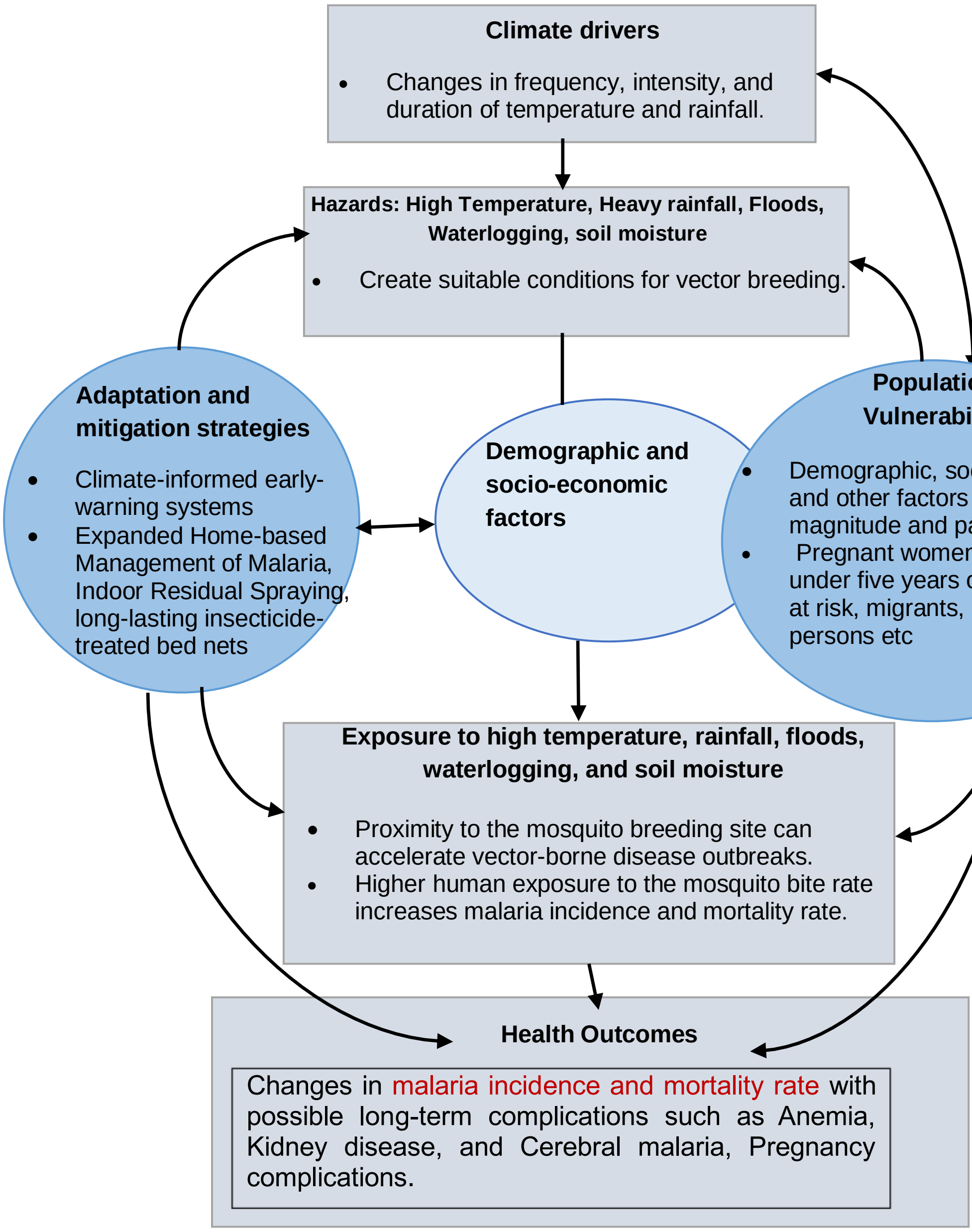
Figure 1 below visually represents the pathway between climate change and malaria. It illustrates that in the absence of adaptation and mitigation strategies, the escalating frequency, intensity, and duration of temperature and rainfall patterns will create favorable conditions for vector breeding. Consequently, this results in an expanded distribution of malaria in terms of geographical extent and temporal occurrence. Studies have highlighted the significant impact of rainfall, temperature, and humidity on spatial and temporal risk of malaria[15].

Additionally, climate change worsens disparities among vulnerable populations, thereby perpetuating health and socio-economic development inequalities. Given that underdeveloped nations bear the greatest burden of malaria, low socio-economic status, coupled with limited access to healthcare services may further amplify the detrimental impact of climate change on health outcomes[12,15]. These vulnerable populations primarily comprise children below the age of five, pregnant women, at-risk occupational groups, disabled, migrants, and low-income groups[3].

Nevertheless, appropriate public health interventions, such as climate-informed early-warning systems for public awareness, detection, prevention, and treatment of malaria, could reduce the health impact of climate hazard exposure. For malaria specifically, measures such as using long-lasting insecticide-treated bednets, indoor residual spraying, malaria chemoprophylaxis, and implementing Expanded Home-based Management of Malaria (EHBM) could be considered[15,16].

In the absence of adaptation and mitigation strategies, higher human exposure to mosquito bite rates due to changes in climatic factors could increase malaria incidence and mortality rates with possible long-term complications such as Anemia, Kidney disease, and Cerebral malaria.

Figure 1 - Pathways between climate change and malaria



2. Health Impacts

The health impact of interest from this topic area is the malaria death and malaria-reported cases attributable to climate hazards. Malaria-reported cases include those that were recorded at hospitals as outpatient diagnoses and those that were hospitalized for severe cases. These health outcomes are of interest because of the increasing concern about malaria risk in tropical and subtropical regions of the world and its impact on children and pregnant women in particular. Moreover, malaria is commonly known as a seasonal or endemic disease and sensitively reacts to short-term variations in rainfall, humidity, and temperature[15]. For the alpha framework, this topic considers the short-term climatic impacts on malaria-reported cases at local, regional, and national levels.

Malaria disproportionately affects vulnerable populations, particularly in low-income regions, and certain groups face a higher risk of severe illness or death. These include children under 5, pregnant women, people living with HIV/AIDS, displaced persons, and populations in conflict zones. In 2022, there were 249 million malaria cases globally leading to 608,000 deaths in total[3]. Of these deaths, 76% were children under five years of age[3]. Moreover, it is also noted that 94% of malaria cases and deaths occur in sub-Saharan Africa in 2022, making it the most affected region in the world. An estimated 10,000 maternal deaths and 100,000 newborn deaths are attributable to malaria each year worldwide and half of this occurs in this region[17]. Therefore, the proposed indicators within this topic consider malaria case disaggregation by including those specific vulnerable groups.

3. Framework Indicators

Several existing frameworks have highlighted the need to prioritize indicators that assess the interaction between climate change and health. These frameworks include the UN Global Set Framework, the Framework for the Development of Environment Statistics (FDES), the Lancet Countdown Framework, the Sendai Framework, the Sustainable Development Goals (SDGs), and the Paris Agreement. In the UN Global set framework, It is well acknowledged that climate conditions have a significant impact on vector-borne diseases such as Lyme disease (ICD-10 code: A69.2), yellow fever (ICD-10 code: A95), West Nile virus (ICD-10 code: A92.3), dengue (ICD-10 code: A97), malaria (ICD-10 codes: B50-B54), and African trypanosomiasis (sleeping sickness) (ICD-10 code: B56).

Moreover, the Lancet Countdown framework includes prioritized indicators that assess the impact of climate change on the transmission of infectious diseases such as dengue, malaria, vibrio, and West Nile virus. The framework encompasses metrics such as extreme temperatures and precipitation as climate hazards, the exposure of populations and health systems to these hazards, and vulnerability factors such as mosquito-borne diseases[18].

This topic examines the relationship between climate factors and vector-borne diseases. It focuses on how extreme temperatures and precipitation affect malaria deaths and hospital admissions. The topic identifies indicators and metrics grouped into three categories: headline outcome indicators included in this topic's alpha framework development, supplementary outcome indicators that may be included in beta framework delivery, and other relevant metrics.

3.1 Headline Outcome Indicators

The headline outcome indicators focus on malaria-reported cases. Malaria-reported cases grouped Outpatient diagnoses for malaria and recorded hospitalized cases. The following headline framework indicators are considered:

- **B1:** Malaria cases attributable to extreme precipitation/rainfall[i]
- **B2:** Malaria cases attributable to extreme temperatures

Due to data limitations in some countries, indicators are provided to produce monthly estimates of the short-term impact of climate change on malaria cases, for both death and hospital admission. However, if daily or weekly observations are available, daily or weekly estimations could be considered. The proposed indicators cover Malaria hospital admission cases associated with extreme precipitation or rainfall, and extreme temperature exposures, respectively. These two indicators are prioritized for being developed as the alpha framework.

For these indicators, extreme precipitation is defined based on whether a month is classified as extremely dry, moderate, or extremely wet. There are no existing standard defined thresholds for classifying a day or month as dry, moderate, or extremely wet. However, the classification is usually based on a relative or absolute threshold definition. For the proposed indicators, relative rather than absolute thresholds are considered. Absolute precipitation is converted into precipitation percentile following the existing method[8,19]. Thus, a month is defined as extremely dry, wet, or extremely wet depending on whether the percentile of the cumulative precipitation for a day/month is below, within, or above a designated reference threshold.

The concept of minimum rainfall risk is used in the calculation of these proposed indicators. It refers to the range of rainfall levels during which malaria mortality and hospital admissions are at their lowest[8]. Existing studies have used the 5th and 95th percentiles as reference thresholds for extremely dry and extremely wet precipitation respectively[8,19].

In addition, a month with extremely low temperatures is referred to as the coldest month if the temperature is below the reference thresholds, and extremely high

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[i] Temporary indicator numbers have been assigned for reference during the development of the SOSCHI framework and will change in the final version.

temperatures are referred to as hot months/days if the temperature is above the defined threshold[8].

3.2 Supplementary Outcome Indicators

In addition to the headline indicators, four additional outcome indications are also considered, including those relevant in assessing the interaction between malaria cases and exposure to flood severity[13]. These supplementary outcome indicators include:

- **B3:** Malaria deaths attributable to extreme precipitation
- **B4:** Malaria deaths attributable to extreme temperatures
- **B5:** Malaria hospital admission cases attributable to flood severity.
- **B6:** Malaria deaths attributable to flood severity

Indicators B3 and B4 are designed to follow the approach developed for indicators B1 and B2. For indicators B5 and B6, flood severity measures are defined based on the Standardized Precipitation Evapotranspiration Index (SPEI) and Standardized Precipitation Index (SPI) set in the UN Global Set framework. SPEI calculates the climatic water balance by comparing the available water content of soil and vegetation with the atmospheric evaporative demand[20]. Flood exposure is defined as SPEI ≥ 0.5 and non-flood exposure is SPEI < 0.5 [21].

3.3 Other relevant measures

Three other indicators could also be included in our framework. These indicators are included in the table below. The proposed indicator B7 includes additional climate hazards that could contribute to malaria vector breeding. Following the UN Global set framework, the temperature-humidity index is considered. This indicator measures the impact of relative humidity, soil moisture, and runoff water on malaria death and hospital admission[14].

Indicator B8 is proposed to capture the exposure and vulnerability factors. It measures the exposure of vulnerable populations to vector breeding sites due to increasing climate hazards. Metrics such as vegetation cover and surface runoff are included in this analysis. Vegetation cover is measured using the Normalized Difference Vegetation Index (NDVI), a dimensionless index commonly used to assess neighborhood greenness[22,23].

Lastly, the proposed Indicator B9 is an adaptation measure that captures the climate-informed early-warning systems, the health sector response strategy plan. This can include the number of households covered by climate-informed early-warning systems, the number of households using the expanded home-based management of malaria, indoor residual spraying, and the insecticide-treated net access, use, and nets-per-capita [24].

Table 1: Other relevant measures

ID	Topic sub-area	Indicator	Measuring	Related Indicators
B7	Vector-borne: Malaria	Temperature-humidity index (Relative humidity, soil moisture), altitude, runoff, waterlogging.	Hazard	UN: Climate Change Statistics and Indicators Self-Assessment Tool The Lancet Countdown
B8	Vector-borne: Malaria	Exposure of vulnerable populations to vector breeding sites due to increasing climate hazards. Urban Vegetation Index.	Exposure and Vulnerability	UN global set of climate change statistics and indicators metadata UKHSA Climate change and public health indicators scoping review: Water quality and quantity and their health impacts The Lancet Countdown
B9	Vector-borne: Malaria	Climate-informed early-warning systems, health sector response strategy plan	Adaptation	The Lancet Countdown

4. Proposed beta phase developments

The alpha framework prioritized indicators of malaria-reported cases attributable to extreme rainfall and temperature (B1 and B2). The method and codes for these prioritized indicators are currently in development and will be included in the beta phase documentation. Indicators of malaria deaths related to extreme rainfall and temperature (B3 and B4) are designed to adopt the proposed method for prioritized indicators and may be included in the beta phase. In addition to these indicators, indicators of malaria hospital admission cases and deaths attributable to flood severity (B5 and B6) may also be incorporated in the beta phase. As part of the beta phase, additional work will be undertaken to detail the limitations and future developments of current data and methods within this topic.

5. Comparison to existing frameworks

The proposed indicators here could be compared to the following existing framework:

- SDGs: Targets 3.3

One of the main objectives of the SDG Target 3.3 is to eradicate the malaria epidemic by 2030. This includes reducing malaria case incidence by at least 90%, cutting malaria mortality rates by at least 90%, eliminating malaria in at least 35 countries, and preventing the resurgence of malaria in all malaria-free countries. Achieving this target requires addressing the environmental and climate factors contributing to malaria transmission. Among these, extreme temperature and rainfall patterns, driven by climate change, are key contributors to the increase in malaria cases. Therefore, quantifying this interaction may contribute to policy orientation in achieving this target by 2030.

- Paris Agreement: Article 7; 13.8

The Paris Agreement focuses on addressing climate change through adaptation and mitigation efforts. Both Article 7 and Article 13.8 of the agreement are relevant when considering the link between climate change and health impacts, particularly diseases like malaria, which are increasingly influenced by extreme temperature and rainfall patterns driven by climate change. Article 7 highlights the need for integrating climate risk assessments such as those for extreme temperature and rainfall patterns into health adaptation strategies. By using climate data to predict and manage malaria outbreaks, countries may better prevent and mitigate the health risks posed by climate change, ultimately contributing to reducing malaria cases. Article 13.8 encourages the transparent monitoring and reporting of climate change impacts. This includes documenting the direct relationship between climate variables such as extreme temperatures and rainfall and malaria transmission patterns. Sharing this information may inform international best practices and help countries design climate-resilient health policies.

- Sendai Framework: Target A, B

The Sendai Framework for Disaster Risk Reduction 2015–2030 aims to reduce the risks and impacts of disasters, including health emergencies, by strengthening resilience and response mechanisms. Concerning malaria cases associated with extreme temperatures and rainfall, Sendai Framework targets are relevant. These targets guide countries in managing the public health impacts of climate-driven events, such as changes in weather patterns that contribute to malaria transmission.

Target A aims to reduce global disaster mortality by 2030. While this traditionally applies to fatalities from immediate disasters, climate-related health impacts like malaria outbreaks driven by extreme weather events such as heavy rains and rising temperatures can be considered under this target, as such outbreaks often follow climate-induced disasters like floods. Target B focuses on reducing the number of people affected by disasters. Malaria, exacerbated by extreme temperatures and irregular rainfall patterns, affects millions, particularly in tropical and subtropical regions.

- Framework for the Development of Environment Statistics (FDES)

The FDES provides relevant indicators linking climate factors, such as extreme temperatures and rainfall variability, with vector-borne diseases like malaria. Under its component 5 "Human Settlements and Environmental Health" and subcomponent 5.2 "Environmental Health", the indicator 5.2.3. of the FDES framework is particularly relevant to the transmission of malaria influenced by climatic factors. It focuses on vector-borne diseases, including the spread of diseases like malaria through vectors. This indicator highlights the importance of gathering and analyzing environmental data on temperature, extreme precipitation, and vector-borne diseases which is crucial for understanding the relationship between climate factors and the pattern of malaria transmission.

- UN Global Set: Indicator 44. Incidence of cases of climate-related diseases

Indicator 44 in the UN Global Set of Climate Change Statistics and Indicators monitors the prevalence of climate-related illnesses directly or indirectly influenced by environmental and climatic changes. This indicator motivates countries to gather and examine data on climate-related health outcomes, including malaria incidence linked to climatic changes such as extreme heat and rainfall. By integrating climate factors with health outcomes, the proposed indicators help decision-makers to identify and track the relationship between climate variability and vector-borne diseases like malaria.

- Lancet Countdown Framework

Two targeted indicators within the Lancet Countdown Framework provide valuable insights into the impact of climate change on vector-borne diseases, specifically malaria cases. These indicators comprise indicator 1.3.2, specific to Malaria, and 2.3.1 which targets vulnerability to mosquito-borne diseases. The first indicator tracks how shifts in seasonal temperatures and precipitation levels affect the climate suitability for these infections and the fluctuations in the length of the malaria transmission season using climatic and environmental conditions required by the vector and the parasite. The second indicator captures the relative vulnerability to severe Aedes-borne disease outcomes by combining increased susceptibility from urbanization, and coping capacity from improved healthcare access and quality.

6. Further reading

- UN global set of climate change statistics and indicators metadata
- United Nations Statistics Division: Draft chapter on environmental health statistics
- Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change
- Six assessment reports of the International Panel on Climate Change. Climate change 2022: impacts, adaptation and vulnerability
- IPCC report Africa, WGIIAR5-Chap22_FINAL, 2018
- Fifth assessment report of the International Panel on Climate Change 2014: Human Health: Impacts, Adaptation, and Co-Benefits
- The Lancet Countdown: Tracking the impacts of climate change on human health via indicators
- The Lancet Countdown: Tracking progress on health and climate change
- World Malaria Report 2023
- UKHSA Climate change and public health indicators scoping review: Water quality and quantity and their health impacts
- Framework for the Development of Environment Statistics (FDES)
- Paris Agreement: Article 7; 13.8

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