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Evaluation of the Eligibility of Haut-Katanga for Seasonal Malaria Chemoprevention in the Democratic Republic of Congo

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Abstract

Context: Despite considerable gains in reducing morbidity and mortality, malaria remains a major health problem due to the deteriorating epidemiological trend over the last eight years. The aim of this study was to analyze the malaria transmission profile in order to adapt control strategies, including SMC (Seasonal Malaria Chemoprevention), for malaria prevention in children under five years of age in the Haut-Katanga province. **Methods:** This was a longitudinal descriptive study that included all cases of malaria in children under 5 years of age recorded in the DHIS-2 (District Health Information Software 2) at the Haut-Katanga Provincial Health Division (National Malaria Control Program: NMCP). Our study sample was exhaustive, with a sample size of 2,535,744 cases. Malaria cases were recorded. The data were extracted from DHIS-2. Data analysis and processing were performed using Excel 2021, QGIS (Quantum Geographic Information System) 3.24, and Stata 18 software. **Results:** Between 2017 and 2024, 2,535,744 cases were recorded in Haut-Katanga. The peak incidences coincided with the rainy season (63.67%). Mortality also showed strong seasonality, reaching a peak crude rate of 0.09 deaths per 1000 Ininhabitants in February. Limited access to insecticide-treated bed nets (36.36%) contributed to maintaining active transmission. **Conclusion:** The study confirms a strong correlation between climate variations and malaria dynamics in Haut-Katanga. The results highlight the importance of intensifying targeted interventions during the rainy season.

Keywords

Seasonal Malaria, Chemoprevention, Child

1. Context

Malaria, a parasitic disease caused by Plasmodium, transmitted to humans through the bite of an infected female Anopheles mosquito, is potentially fatal, but also preventable (with the availability of preventative measures) and curable (with the availability of effective treatment). It remains a major global health threat, particularly in tropical regions where it is more prevalent. Malaria-related deaths recorded in 2024 totaled 21,695, of which 15,091 occurred in children under 5 years of age (69%) [1].

The report highlights notable progress, with 44 countries and 1 territory certified as malaria-free by the WHO [1]. Annually, this parasitic disease poses a substantial risk to over two billion people, particularly in the poorest areas [2]. Africa, and particularly the Democratic Republic of Congo (DRC), is the most affected region, recording millions of cases each year, with high mortality among children under five years old [3]. The WHO's 2023 World Malaria Report states that 94% of Malaria cases (246 million) and 95% of deaths (569,000) occur in the African region, with 78% of deaths occurring in children under 5 years old [4]. The province of Haut-Katanga perfectly illustrates this crisis, with an alarming incidence and hospital mortality rates reaching 28.32% in 2021 [5]. Several factors are worsening the situation: the increasing resistance of the Plasmodium falciparum parasite to common antimalarial drugs and that of the vectors to insecticides[6], non-compliance with care protocols by healthcare staff, as well as unfavorable socio-economic conditions which reinforce the link between poverty and poor health [6]. Furthermore, asymptomatic malaria contributes to maintaining active transmission in endemic areas, with a notable prevalence of 36.57% in Haut-Katanga in recent years [7]. Environmental factors, such as stagnant water and seasonal climate variations, also play a key role in epidemiological evolution [8].

Faced with these persistent challenges, this study aims to analyze the potential seasonality of malaria incidence in the Haut-Katanga province. Over the past eight years; to characterize the temporal evolution of this incidence, while identifying the climatic factors that would impact its dynamics. The study's overall objective was to contribute to the evaluation of the impact of existing and new interventions, individually or combined, on reducing the burden of malaria at different levels of intervention (health zones, provincial coverage) in children under 5 years of age. Specifically, to measure malaria incidence, deaths due to malaria over the last eight years in Haut-Katanga and to determine the possible seasonality of malaria over the last eight years in the province of Haut-Katanga.

2. Study Population and Methods

2.1. Study Framework

This study was conducted in the Provincial Health Division of Haut-Katanga, specifically in the health zones of Katuba, Kisanga, Kampemba, and Kenya, in the Democratic Republic of Congo.

2.2. Study Population and Sampling

The study population consisted of children of both sexes, under 5 years of age, from the Katuba, Kisanga, Kampemba, and Kenya Health Zones. The design was a descriptive longitudinal study based on all Malaria casess in children under 5 years of age. The sample was exhaustive, encompassing 2,535,744 cases recorded in the DHIS-2 database and geo-climatic data.

2.3. Selection Criteria

All data on Malaria cases recorded via DHIS-2 supplemented with meteorological data obtained from the METTELSAT and NOAA station throughout our study period, *i.e.* from January 1, 2017 to December 31, 2024.

2.4. Sample Size Estimation

The study was based on an exhaustive collection of all cases meeting the inclusion criteria, extracted from the DHIS-2 and EpiData v3.1 databases, supplemented by the use of meteorological data from the period studied.

2.5. Data Collection Technique and Seasonality of Transmission

We collected retrospective historical data for the past eight years. We first performed quality control on the provided data, then entered it into Microsoft Excel 2021 to create a database. Longitudinal case data were needed to calibrate the transmission model based on local epidemiology, both in terms of understanding endemicity and the degree of seasonality of transmission (*i.e.*, the proportion of annual clinical cases occurring in four consecutive months).

2.6. Data Processing and Analysis

The collected data were encoded using Microsoft Excel 2021, then exported to QGIS 3.24 and Stata 18 for analysis. The Standardized Incidence Ratio (SIR) was used to study the spatial distribution. The WHO-developed Excel spreadsheet was used for data management and analysis. Analysis of interannual variability and the annual cycle of precipitation and temperature for the selected climate zone was performed using the IPCC Interactive Atlas portal, accessible via the following URL: https://interactive-atlas.ipcc.ch/.

2.7. Data Source, Period and Type of Study

The data were collected at the Provincial Health Division of Haut-Katanga (DPS HK), in DHIS-2, and METTELSAT and NOAA. The study period was from January 1, 2017 to December 31, 2024. This is a retrospective longitudinal descriptive study.

3. Results

3.1. Flowchart

The diagram highlights the importance of considering seasonal factors in the analysis of health data and underscores the need for a response tailored to seasonal variations in illnesses (see Figure 1).

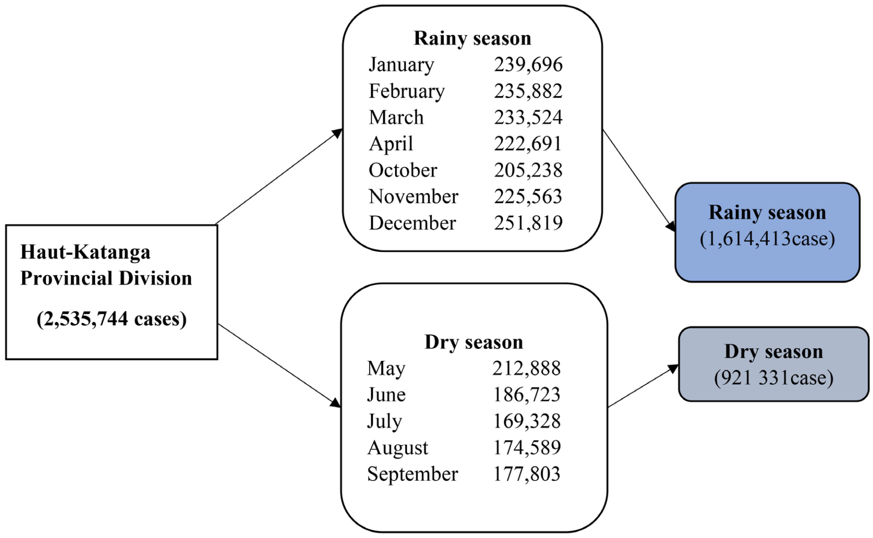


Figure 1. Sample flow diagram (DHIS-2, from 2024).

3.2. Malaria Incidence and Deaths over the Last Eight Years

Analysis of the distribution of Malaria cases reveals that the Health Zones: Katuba (10.88%), Mumbunda (1.8%) and Lubumbashi (1.65%) have a higher proportion than some other Health Zones (see Table 1).

Table 1. Distribution of Malaria cases in urban Health Zones (from 2017 to 2024).

Health Zones	Malaria Cases	Population	(%)
Kamalondo	5528	695,865	0.79
Kampemba	146,338	9,531,409	1.54
Katuba	31,356	288,087	10.88
Kenya	47,865	4,720,239	1.01
Kisanga	103,183	8,614,783	1.20
Lubumbashi	103,795	5,742,825	1.65
Mumbunda	85,439	6,376,909	1.81
Ruashi	178,476	11,280,302	1.34
Tshamilemba	74,937	4,819,738	1.58

This table reveals a clear seasonality in the incidence of malaria in Haut-Katanga. Higher incidence rates are observed during the rainy season (63.67%), with peaks reaching 58.97 cases per 1000 Ininhabitants. Conversely, the dry season sees low incidence rates (36.33%). The highest SIR was 0.10 (R < 1) (see Table 2).

Analysis of malaria impact indicators reveals mortality during the rainy season, particularly in February, where the incidence rate is 0.15%, with a peak crude mortality rate of 0.09 deaths per 1000 Ininhabitants. This indicates an increased severity of malaria during the rainy season, unlike the dry season (see Table 3).

Table 2. Malaria incidence by season (from 2017 to 2024).

Season	Month	Malaria cases	SIR	Incidence per 1000 Ininhabitants.
Rainy season (63.67%)	January	239,696	0.09	56.13
	February	235,882	0.09	55.24
	March	233,524	0.09	54.69
	April	222,691	0.09	52.15
	October	205,238	0.08	48.06
	November	225,563	0.09	52.82
	December	251,819	0.10	58.97
Dry season (36.33%)	May	212,888	0.08	49.86
	June	186,723	0.07	43.73
	July	169,328	0.07	39.65
	August	174,589	0.07	40.89
	September	177,803	0.07	41.64

Table 3. Malaria mortality indicators in Haut-Katanga by season from 2017 to 2024.

Season	Month	Death	Mortality (%)	TBM per 1000 Ininhabitants.
Rainy season	January	241	0.10	0.06
	February	363	0.15	0.09
	March	216	0.09	0.05
	April	158	0.07	0.04
	October	234	0.11	0.05
	November	210	0.09	0.05
	December	224	0.09	0.05
Dry season	May	190	0.09	0.04
	June	191	0.10	0.04
	July	111	0.07	0.03
	August	88	0.05	0.02
	September	94	0.05	0.02

A general downward trend in incidence rates was observed in four areas. Kampemba had the highest rates, reaching up to 11.62 cases per 1000 children, while Katuba had the lowest, around 7.79 cases per 1000 children. In particular, December corresponds to a period of high malaria seasonality in all the health zones studied (see Figure 2).

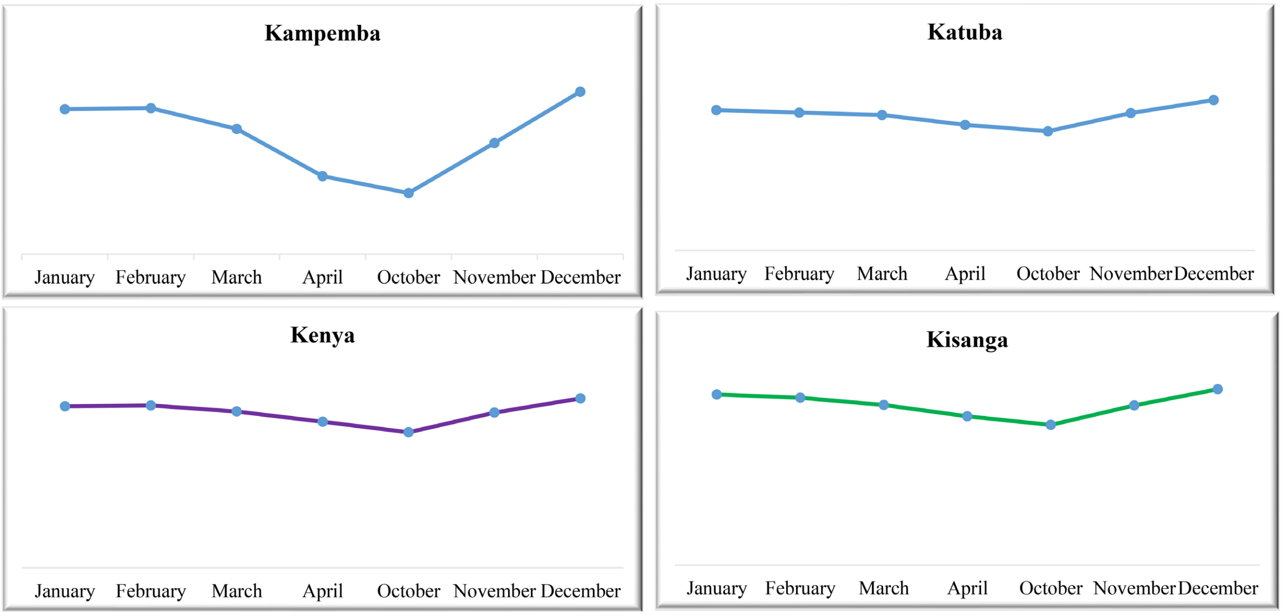


Figure 2. Evolution of malaria incidence rates in children under 5 years of age during the rainy season for 96 months in 4 Health Zones.

For Figure 3, the year 2024 shows a low proportion of deaths and a stable trend; but compared to 2025, here we note a gradual increase, with peaks in January and August (see Figure 3).

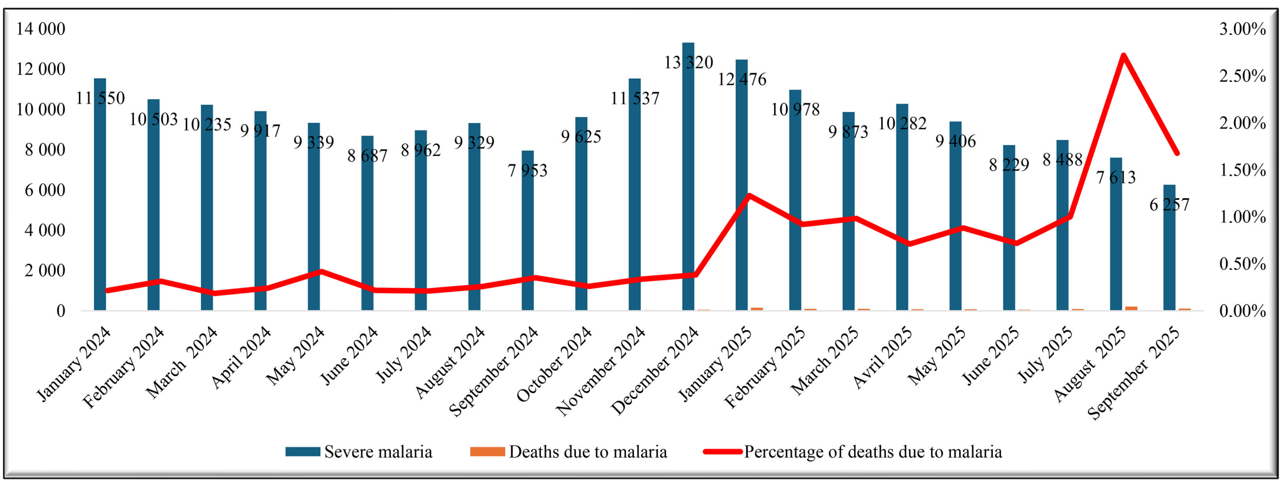


Figure 3. Comparative evolution of the proportion of deaths due to malaria among 5-year-old children from January to December 2024 and from January to September 2025.

Figure 4 shows the distribution of malaria deaths by year in Haut-Katanga. The highest peak in malaria mortality can be observed in 2017, when the mortality rate reached 21.21%, indicating a significant resurgence of malaria-related deaths. After 2020, a general downward trend in mortality rates is noted, falling to 3.86% in

2024 (see **Figure 4**).

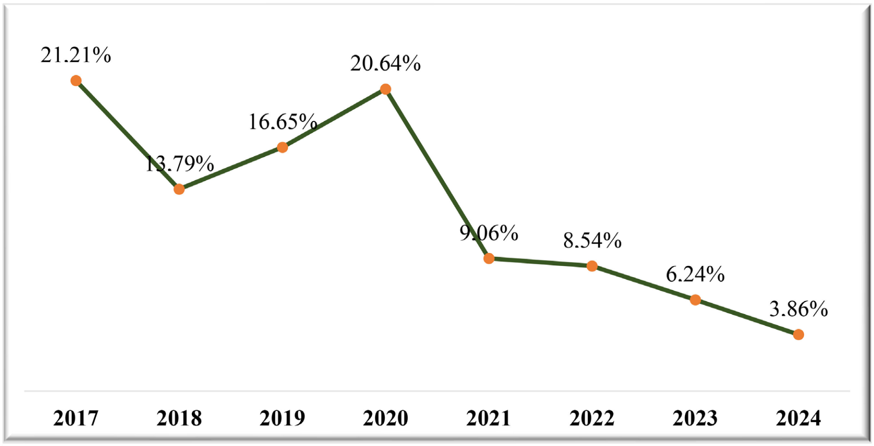


Figure 4. Distribution of deaths due to malaria per year.

3.3. Seasonality of Malaria in the Haut-Katanga Province

All study areas show the highest incidence of malaria, corresponding to the rainiest sectors with an annual average of 111 mm of rainfall. Abundant rainfall creates an environment conducive to the proliferation of mosquito vectors. Similarly, these most affected areas are also those with the highest humidity levels, averaging 61.95 g/m^3 per year. Humidity plays a crucial role in larval development and adult survival (see **Figure 5**).

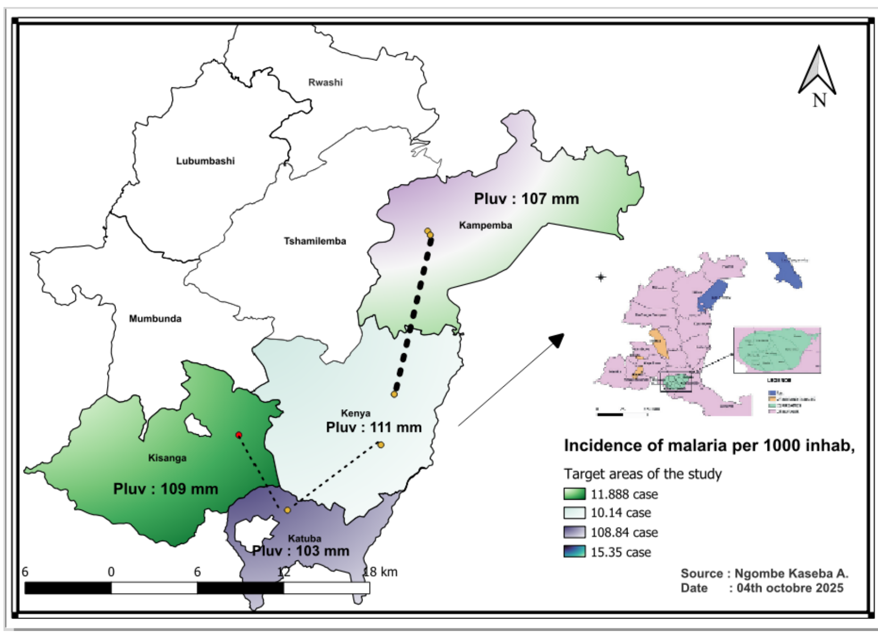


Figure 5. Standardized and spatio-temporal incidence rates of the target Health Zones (from 2017 to 2024).

The meteorological data shown in the map below, including temperatures and rainfall, have a significant influence on the transmission and spread of malaria in these health zones.

Heavy rainfall, varying from 103 mm to 115 mm depending on the area, creates numerous breeding grounds for mosquitoes, which are conducive to the proliferation of mosquito vector populations. Areas with the highest rainfall, such as Kenya with 111 mm, are therefore particularly at risk for malaria transmission (see Figure 6).

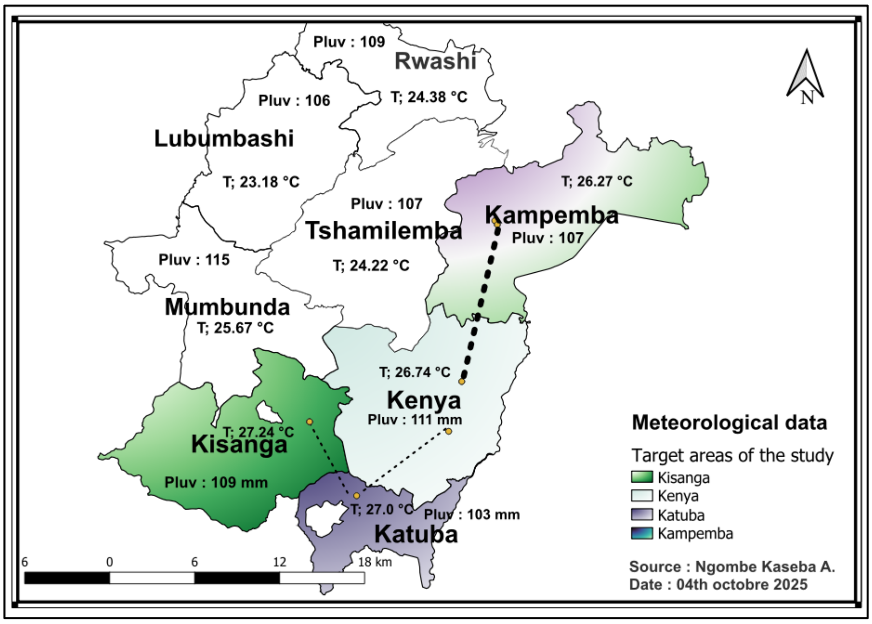
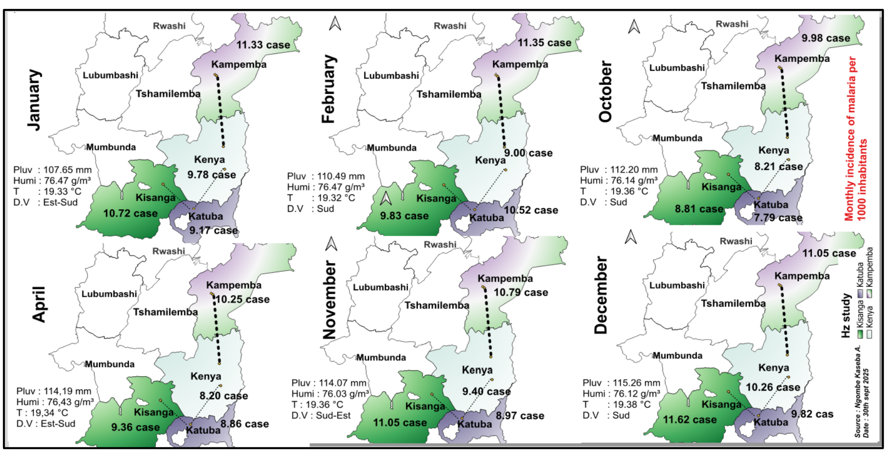
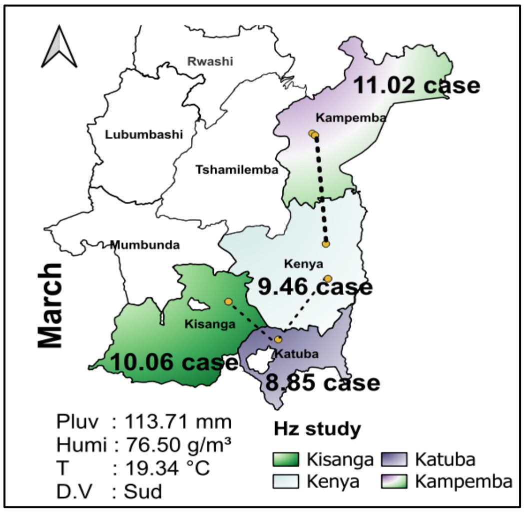


Figure 6. Meteorological data in Health Zones (from 2017 to 2024).

Malaria incidence rates among children under 5 years of age in the 4 studied Health Zones show notable differences between the zones. Kampemba has the highest rates, reaching up to 11.62 cases per 1000 children in December with high rainfall (115.26 mm) and high humidity (76.12 g/m³); these meteorological conditions also facilitate the survival and longevity of adult mosquitoes, increasing their ability to transmit the parasite (see Figure 7).



(a)



(b)

Figure 7. Meteorological maps of monthly incidence rates during the rainy season in the target Health Zones (from 2017 to 2024).

The IRR decreases slightly with increasing precipitation, but the p-value with a 95% CI indicates that this relationship is not statistically significant (see Table 4).

Table 4. Meteorological influence on the incidence rate of malaria in children under 5 years of age during the rainy season (2017 to 2024).

Month	Impact	Average precipitation	IRR	p-value	IC 95%
January	56.13	107.65	1000	0.940	[0.959; 1.040]
February	55.24	110.49	0.994	0.933	[0.872; 1.133]
March	54.69	113.71	0.996	0.891	[0.936; 1.059]
April	52.15	114.19	0.989	0.702	[0.933; 1.047]
October	48.06	112.20	0.966	0.430	[0.888; 1.052]
November	52.82	114.07	0.991	0.751	[0.934; 1.050]
December	58.97	115.26	1.007	0.791	[0.959; 1.056]

Rainfall conditions of Lubumbashi have been rare for the past 90 days, with temperatures close to normal (METTELSAT and NOAA) (see Figure 8).

4. Discussion

4.1. Malaria Incidence and Deaths over the Last Eight Years in Haut-Katanga

Our analysis of malaria incidence in the 27 health zones of Haut-Katanga shows it to be between 145.73 and 216.73 cases per 1000 Ininhabitants over the period from 2017 to 2024 [2]. These findings demonstrate that several factors can influence the incidence rate, including climatic conditions, insecticide resistance, and access to healthcare. It is also important to note that the incidence of malaria in our study varies seasonally, with peaks often observed during the rainy season.

Furthermore, according to the WHO, multiplying our results by the rate of self-medication with antimalarials, which ranges from 0.2% to 0.3% in the DRC, results in a higher incidence. Malaria transmission is strongly correlated with climatic variations, as explained by the fluctuations observed in our data. Our analysis shows that the average malaria incidence during the rainy season is significantly higher than the reference average, the increase was marginally significant at the 0.10 threshold (p = 0.086) [3]. This increase can be attributed to environmental conditions favorable to the reproduction of mosquitoes, vectors of malaria, and to a proliferation of cases due to increased exposure of populations to these vectors [3].

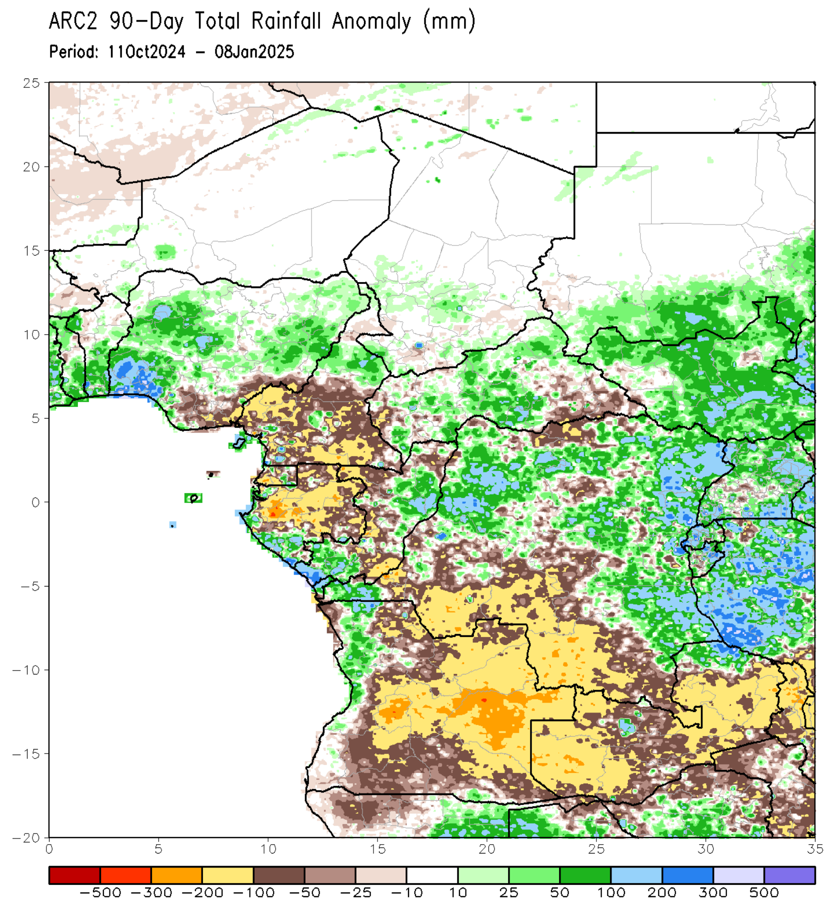


Figure 8. Annual precipitation cycle.

These results are consistent with observations from other studies conducted in similar regions of sub-Saharan Africa, which have also highlighted seasonal peaks in malaria mortality, often occurring during the rainy season, thus promoting mosquito proliferation. In Burkina Faso, in areas under SMC (Seasonal Malaria Chemoprevention), the Mortality Rate fell from 15% in 2016 to 8% in 2020, before rising slightly to 10% in 2021 [3]. These results demonstrate the effectiveness of this intervention, even though access and coverage remain limited in some areas. The study shows that implementing the fifth round is feasible and can help improve malaria prevention in regions where the disease is long-lasting.

The trend in the proportion of deaths between January and September 2024 and 2025 highlights a marked resurgence in 2025, contrasting with the relative stability observed in 2024. This increase in mortality represents a major challenge for the health system in Haut-Katanga. Our results are consistent with those reported by Éric Mukomena *et al.* [9]. In Lubumbashi and Haut-Katanga, the mortality rate from severe malaria has fluctuated between 1% and 2% depending on the year and the hospital, but has remained generally below 2% in most recent reports [9]. This could also be due to the reduction of American aid to the NMCP, PMI/USAID according to the report on the availability of antimalarial drugs to the NMCP in the PHD Haut-Katanga; evidence embracing spatio-temporal analysis suggests a direct link between seasonal fluctuations and the increased spread of malaria in the Haut-Katanga province [9].

Nevertheless, the peak of over 2.5% observed in August 2025 suggests an exceptional event or a one-off failure in the management of severe cases or access to care. Mukomena also highlighted the barriers related to late diagnosis, self-medication, and the use of unqualified private facilities, which are aggravating factors for mortality [8]. Taking the 2023 annual report, the nationally, data from the National Malaria Control Program (NMCP, DRC) also report a Mortality Rate varying between 1% and 2.5% among those hospitalized for severe malaria depending on the province, with peaks during seasons of high transmission.

In Africa, deaths from severe malaria remain a concern, particularly among children under 5. A multicenter review across the continent reported case fatality rates between 1% and 8%, depending on access to intensive care, the availability of injectable artesunate, and the strain on healthcare facilities during epidemics [1] [10]. This is the case, for example, in Nigeria and Uganda, where studies consistently report rates exceeding 4% in rural areas [10]. According to the WHO, in 2023, in countries outside of Africa, mortality from severe malaria is much lower, often less than 1% thanks to robust health systems and rapid treatment (Europe, Southeast Asia).

4.2. Seasonality of Malaria in the Haut-Katanga Province

The seasonality of climatic variables is clearly observable. Our results confirmed the presence of a significant seasonal pattern of malaria in Haut-Katanga over the past eight years (2017-2024). However, the peak incidence of malaria varied between December and January, with rates ranging from 56.13 to 58.97 cases per 1000 children, correlating with high average rainfall (115.26 mm) and high humidity (76.12 g/m^3). The incidence rate reached its lowest point in October, at 48.06%. These results are also consistent with those of Mukomena E. [9], which observed a 2-month time lag between malaria incidence and rainfall/temperatures for historical data, while a 1-month lag was noted for recent data.

By analyzing the rainfall profile preceding the seasonal peak in incidence (December-January), we observed a decrease of approximately 7.61 mm for 3 Malaria cases, falling from 115.26 mm to 107.65 mm between historical climatological data points, thus exceeding the critical sporogony threshold. It therefore appears that the constraints related to low temperatures on malaria transmission at the beginning of the rainy season have decreased in recent years, which could explain the temporal shift of the incidence peak in Haut-Katanga [11]. The relatively high temperatures, between 24˚C and 27˚C (Kampemba, Katuba, Kisanga, Rwashi), are conducive to the development of the malaria parasite (Plasmodium) and its vector, the Anopheles mosquito. Warmer temperatures accelerate the parasite's life cycle and promote mosquito reproduction.

Future increases in minimum temperature could raise the incidence of malaria up to an optimal temperature limit, in line with forecasts for many mountainous regions of sub-Saharan Africa [12]. Furthermore, our analyses indicate that changes in rainfall or maximum temperature trends are less likely to influence changes in malaria incidence in the region.

In comparison, the studies by Hay *et al.* [11], revealed differences in malaria incidence across geographical areas, a phenomenon we also observe in our analysis. The lower incidence rates in the Kisanga, Kenya and Katuba areas, around 57 to 61 cases per 1000 children respectively, can be attributed to less favorable weather conditions for mosquito breeding during the rainy season, as suggested by Lindsay *et al.* [12], who noted that less rainy areas tend to have a reduced incidence of malaria by Bouma [13], reinforce this perspective by showing that seasonal changes in rainfall and humidity can affect vector life cycles.

Regarding the impact of the high rainfall in December (115.26 mm) and the high humidity (76.12 g/m^3), these observations are consistent, as they promote larval development and mosquito survival. Overall, our results align with data from the literature, highlighting the major influence of climatic factors (rainfall and humidity) on malaria dynamics.

4.3. Limitations of the Study

We note an absence of population counts for children under 5 years of age between 2017 to 2022 as a benchmark in the Health Zones; this means that we did not have a common denominator for the annual and monthly incidence of malaria in the Health Zones.

5. Conclusion

This study demonstrates that malaria incidence in Haut-Katanga exhibits strong seasonality, with transmission peaking during the rainy season. Seasonal chemoprevention is essential to reduce morbidity and mortality, with significant results observed during the rainy season in Haut-Katanga, a region typical of the Sahel. Furthermore, Integrated Management of Childhood Illness (IMCI), the use of insecticide-treated bed nets (ITNs), Indoor Residual Spraying (IRS), and vaccination is crucial. Climatic conditions, particularly rainfall and temperature, strongly influence malaria transmission. Therefore, SMC could be considered as part of targeted subnational interventions to reduce the prevalence of malaria in Haut-Katanga, especially among the most vulnerable populations. Finally, the establishment of an effective surveillance system and the mobilization of additional resources are essential to adapt interventions in real time and inform communities about malaria prevention and treatment.

Acknowledgments

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Author's Contributions

ANK and EMS: Conception, study design and tools, data acquisition, drafting the article, and revising it critically for important intellectual content.

ESK, AMM and NKN: contributed to revising it critically for important intellectual content and methodological contribution.

ANK and EMS: analysis and interpretation; ESK, AMM and NKN: Literature search, manuscript: all. All authors have read it.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics Approval and Administrative Factors

This study stems from the research project registered under approval No. UNILU/CEM/028/2025 by the Research Ethics Committee of the University of Lubumbashi. All data collection tools were coded to preserve anonymity. Ethical principles were respected, and we also obtained the consent of the health zone officials involved in the study. Confidentiality and dignity were guaranteed. The authorities and communities in the study area were informed of the study's objective; an information sheet was provided to them, and their approval was requested during the study presentation meeting.

Conflicts of Interest

The authors declare that they have no competing interests.

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Abbreviations

ACT: Arthemisinin Combination Therapy; AQ: Amodiaquine; HA: Health Area; CDC: Center for Disease Control; PC: Antenatal Consultation; HC: Health Center; DHIS2: District Health Information Software 2; PHD: Provincial Health Division; SPH: School of Public Health; HK: Haut-Katanga; ITN: Insecticide-Treated Nets; WHO: World Health Organization; NMCP: National Malaria Control Program; PMI-USAID: President's Malaria Initiative-United States Agency for International Development; DRC: Democratic Republic of Congo; SMC: Seasonal Malaria Chemoprevention; UNILU: University of Lubumbashi; HZ: Health Zone.