

Health Service Disruption During the 2024 Floods in Yagoua Health District, Cameroon: A Descriptive Study

Samira AMADOU¹

amadsamishams@yahoo.com

Ministry of Public Health

Linda ESSO¹

University of Yaoundé I

Serge BILLONG¹

University of Yaoundé I

Sunjoo KANG

Yonsei University

Article

Keywords: floods, health services, Cameroon, disaster health, health system resilience

Posted Date: October 23rd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10461742/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Health Service Disruption During the 2024 Floods in Yagoua Health District, Cameroon: A Descriptive Study

Dr Samira AMADOU¹; Dr Linda ESSO^{1,2}; Prof. Serge BILLONG^{1,2}; Prof. Sunjoo KANG³

¹ *Department for Disease, Epidemic and Pandemic Control, Ministry of Public Health, Yaoundé, Cameroon*

² *Faculty of Medicine and Biomedical Sciences, University of Yaoundé I, Yaoundé, Cameroon*

³ *Graduate School of Public Health, Yonsei University, Seoul, Republic of Korea*

Corresponding author: Dr Samira AMADOU

Email of the corresponding author: amadsamishams@yahoo.com

Abstract: floods are increasing globally, yet their impact on health service delivery in sub-Saharan Africa remains poorly documented. This descriptive study examined eight essential health indicators in the Yagoua Health District, Cameroon, during the July–September 2024 flood period, using secondary data from the national DHIS2 system. Monthly trends in vaccination, outpatient consultations, hospitalizations, deaths, severe acute malnutrition, community births, malaria cases, and antiretroviral therapy were analyzed. Percentage change and the Kruskal–Wallis test compared flood-period months across 2023, 2024, and 2025. Vaccination declined by 5.5%, while hospitalizations rose 38%, malnutrition cases 51.8%, community births 48.4%, and malaria cases 77.6%. The Kruskal–Wallis test showed no statistically significant differences across years, though community births ($p = 0.061$) and hospitalizations ($p = 0.066$) approached significance. Despite non-significant statistical differences, observable trends indicate substantial operational strain on health services during floods. These findings highlight the vulnerability of rural health systems to environmental shocks and underscore the need for targeted disaster preparedness strategies in flood-prone regions of sub-Saharan Africa.

Keywords: floods, health services, Cameroon, disaster health, health system resilience

Introduction

A flood is defined, according to the Oxford Reference Dictionary (ORD), as an overflow or influx of water that exceeds its usual boundaries. This phenomenon generally occurs when a body of water, such as a river, lake, or stream, holds more water than its capacity, causing it to overflow into surrounding areas (Glago, 2021). Floods are the most frequent natural disaster globally, and their future incidence is expected

to rise, due particularly to the effects of climate change and demographic dynamics (Allan & Soden, 2008; WHO, 2020).

Climate change is often linked to an increase in the frequency and intensity of extreme weather events, such as hurricanes, cyclones, and tsunamis, which can lead to flooding (Adams, 2008). Regional floods are also favored by an unusual increase in the duration and intensity of rainfall, causing a rapid rise in river levels followed by slow runoff, potentially inundating large areas (Abbott, 2006).

Additionally, unplanned urbanization, combined with inadequate drainage systems, is a well-documented aggravating factor in the scientific literature (Zhang et al., 2018). The impacts of flooding on populations are multifaceted: loss of essential infrastructure (Glago, 2021), major economic losses, disruption of public services, and significant consequences on public health (Allaire, 2018).

Studies have highlighted the effects of flooding on health systems, including destruction of health infrastructure, interruption of services, loss or resignation of medical personnel, and sometimes even their deaths (Lorenzoni et al., 2020). They also show that low-income households are often forced to reduce spending on education and preventive health care to meet basic survival needs.

Among the most disrupted health services, routine vaccination ranks high. This disruption is due both to population displacement and to breaks in the cold chain, rendering vaccines ineffective. Other studies report a decrease in medical consultations and hospital admissions, as well as an increase in deaths during flood periods (Alderman et al., 2012).

Flooding is also associated with an increase in vector-borne diseases (Mwachui et al., 2015), particularly in Africa. It promotes the proliferation of stagnant water, which serves as a breeding ground for malaria-carrying mosquitoes (Tabassum et al., 2023).

The Far North region of Cameroon is one of the most exposed to flooding during the rainy season. In 2024, a major flood occurred between July and September, affecting around 459,102 people and destroying over 56,000 houses. Among the most affected departments was Mayo-Danay, whose capital is Yagoua (OCHA, 2024b).

Although this disaster led to a considerable humanitarian response, few studies have been conducted to assess its impact on the health of affected populations, particularly their use of essential health services. It is therefore crucial to examine how key indicators of healthcare demand evolved in the affected areas, especially in the Yagoua Health District.

This study was thus designed to address that gap. Its primary objective is to describe the evolution of essential health care utilization indicators during the flood period, to highlight potential disruptions in health service use in the Yagoua District.

Methodology

Context

Cameroon, located in Central Africa, has two main climate types: an equatorial climate in the south, with rainfall up to 2,000 mm/year, and a Sahelian climate in the north, much drier, with annual rainfall ranging from 400 to 1,200 mm depending on the locality((DMN), 2024). The Far North region, subject to seasonal rains between June and September, is regularly affected by floods, particularly in areas near the Logone River. In cities like Yagoua, average annual rainfall varies between 900 and 1,100 mm, with over 80% of rainfall occurring between June and September(Data, 2024). Major floods have been recorded in 2012, 2014, 2020, and more recently in 2024(OCHA, 2024a). Despite the recurrence of these events, their impact on the use of health services remains poorly documented.

Study Type

This is a quantitative descriptive study. Its main aim is to document changes in the continuum of care during the flood period to highlight observed disruptions. The results of this analysis will also serve as a baseline for future in-depth research on the impact of natural disasters on health systems.

Target Population

The target population includes all communities living in flood-prone areas in Cameroon, especially rural areas, for which the study results may be extrapolated.

Source Population

The source population consists of all residents of the Yagoua Health District during 2024, a year marked by flood episodes that affected healthcare access.

Study Population

The study population comprises individuals who sought health services in the Yagoua Health District from January to December 2024. All health facilities in the district that routinely report to the national DHIS2 system were included. No sampling was performed; all available monthly programmatic data for the selected indicators were extracted. All health facilities in the district that routinely report to the

national DHIS2 system were included. No sampling was performed; all available monthly programmatic data for the selected indicators were extracted.

Data Collected

Secondary programmatic data were extracted from the national health data collection system (DHIS2). Complete monthly data for all 12 months were available for 2023 and 2024. For 2025, data were available for January through September only. For descriptive trend analysis, variables were examined over the full 12 months of 2024, allowing for a temporal comparison before, during, and after the floods. For the Kruskal–Wallis comparative analysis, monthly indicator values during the flood-period months (July–September) were compared across the three years: 2023, 2024, and 2025. Data are aggregated at the facility level and contain no personally identifiable information. Potential sources of bias include underreporting during the flood period due to health facility disruptions, incomplete data transmission, and delayed reporting. No additional bias mitigation strategies were implemented beyond using the complete official dataset.

Sample

All available data for each selected variable were included in the study. The study size was determined by data availability. No formal sample size calculation was performed as this study used a complete enumeration of existing secondary data.

Variables Analyzed

The selected variables were determined through an in-depth literature review, which revealed that these indicators are typically affected by flooding. Prior studies have shown that these variables are particularly sensitive to the disruptions caused by natural disasters. These include:

- **Number of children receiving Penta 1 (pentavalent) vaccine:** A key indicator for monitoring the Expanded Program on Immunization (EPI). Routine vaccination can be disrupted during crises such as floods.
- **Number of outpatient consultations per month:** This may decrease due to reduced access or increase due to trauma and illness.
- **Number of monthly hospitalizations:** Floods may increase the need for hospital care or reduce admissions due to inaccessibility or overcrowding.
- **Monthly deaths:** Floods often correlate with increased mortality, both direct (drowning, injury) and indirect (interruption of care, infectious diseases, malnutrition).

- **Cases of severe acute malnutrition among children admitted to facilities:** Floods often worsen food insecurity, especially affecting children under five.
- **Number of community - based births per month:** Reflects barriers to facility-based obstetric care and maternal health service utilization.
- **Confirmed simple malaria cases by community health workers (CHWs) using RDTs:** Malaria is highly sensitive to environmental changes. Community-based RDT screening provides valuable insights.
- **Monthly active cohort on ART (antiretroviral therapy):** As one of the best-structured programs in the country, the HIV program serves as a health system performance indicator.

Analysis

Descriptive and comparative analyses were conducted using Microsoft Excel, with graphical visualization of monthly trends.

Descriptive and comparative analyses were conducted using Microsoft Excel, with graphical visualization employed to illustrate monthly trends in 2024. To assess the immediate impact of the floods on service utilization, the percentage change (variation ratio) was calculated by comparing the month preceding the floods with the month following the end of the flood period. This allowed for the quantification of short-term disruptions in health service use. The percentage change (variation ratio) was calculated to quantify the magnitude of differences between years using the formula:

$$\frac{(Value, in month 2 - Value in month 1)}{Value in month 1} \times 100$$

A negative percentage indicated a decrease in service utilization, whereas a positive percentage indicated an increase.

To assess whether the observed differences were statistically significant across the study period, a group differences analysis was performed using the Kruskal–Walli’s test, which is appropriate for small sample sizes and non-normally distributed data. Monthly indicator values during the flood-affected period were compared across three years (2023, 2024, and 2025). A p-value < 0.05 was considered indicative of statistical significance. The 2025 dataset was truncated at September due to data availability at the time of extraction; this did not affect the flood-period comparison as July–September data were complete for all three years.

The combination of monthly trend visualization and non-parametric testing allowed for both descriptive and inferential assessment of temporal differences in service utilization during the flood-period months.

Ethical Considerations

All methods were carried out in accordance with relevant national and international guidelines and regulations for the ethical use of secondary public health surveillance data.

This study utilized anonymized, aggregated programmatic data extracted from the national DHIS2 health information system. These data are routinely collected for public health disease monitoring and surveillance purposes. They are validated monthly at the health facility level before entry into the system, subsequently reviewed by the district coordination and surveillance teams, and undergo central-level data quality assurance. As this study involved the secondary analysis of existing, fully anonymized, aggregated data containing no personally identifiable information, formal ethics committee approval and informed consent were not required. Data are centrally housed at the Department for Disease, Epidemic and Pandemic Control, Ministry of Public Health, Cameroon. Three of the authors are public health officials serving within this department. Data access and use were authorized through official administrative channels within the Ministry of Public Health hierarchy, in accordance with institutional data governance protocols.

Results

1- Monthly Trends in 2024

Figure 1 below shows the monthly distribution of children vaccinated with the first dose of the pentavalent vaccine (Penta 1) in the Yagoua Health District. During the flood period from July to September, the recorded figures were 982 in July, 951 in August, and 900 in September. This sequence reflects a slight interruption in the vaccination trend, with a gradual decline over these three months. However, from October onwards, the number of vaccinated children gradually increased, reaching 1,047 in October and peaking at 1,055 in November before dropping again to 854 in December. Compared to June (pre-flood) and August (peak of the crisis), analyses revealed a temporary decrease of about 5.5% in the number of children receiving Penta 1.

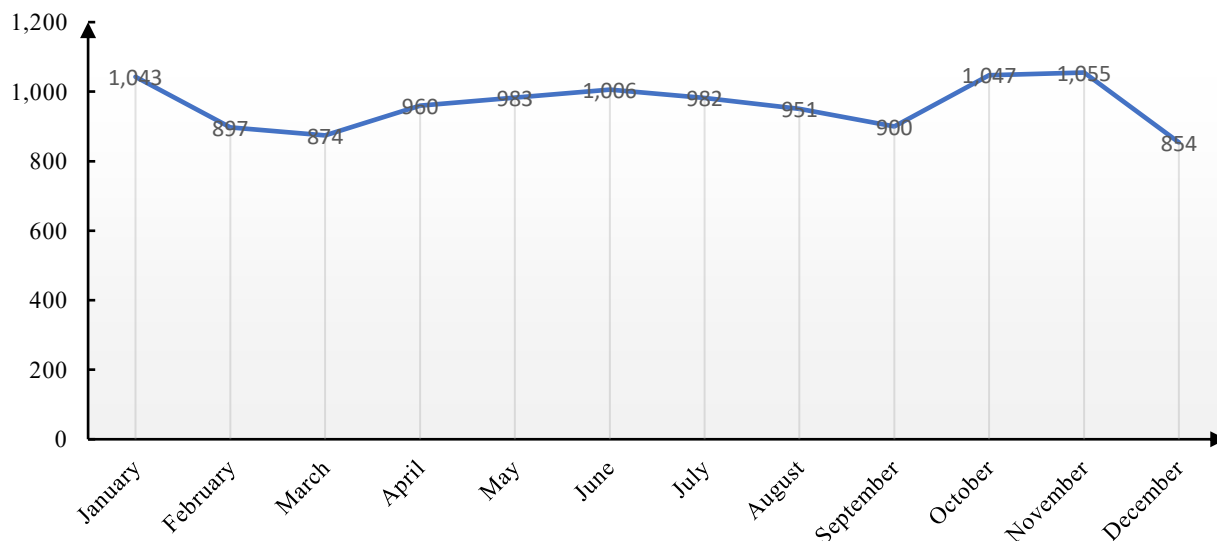
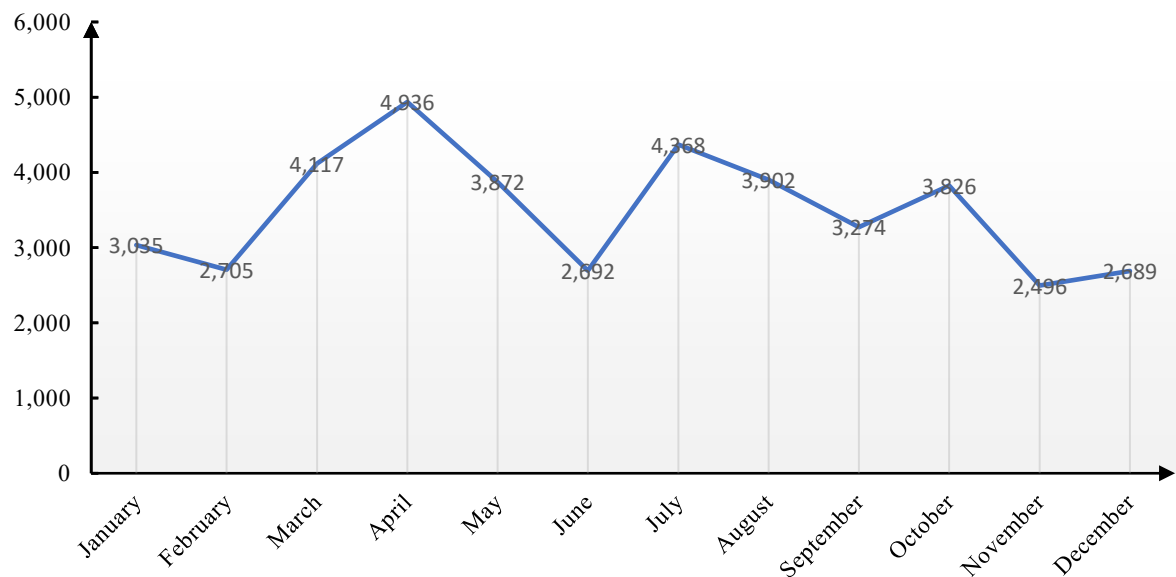


Figure 1: Number of children who received the Penta 1 vaccine during the month in the Yagoua Health District

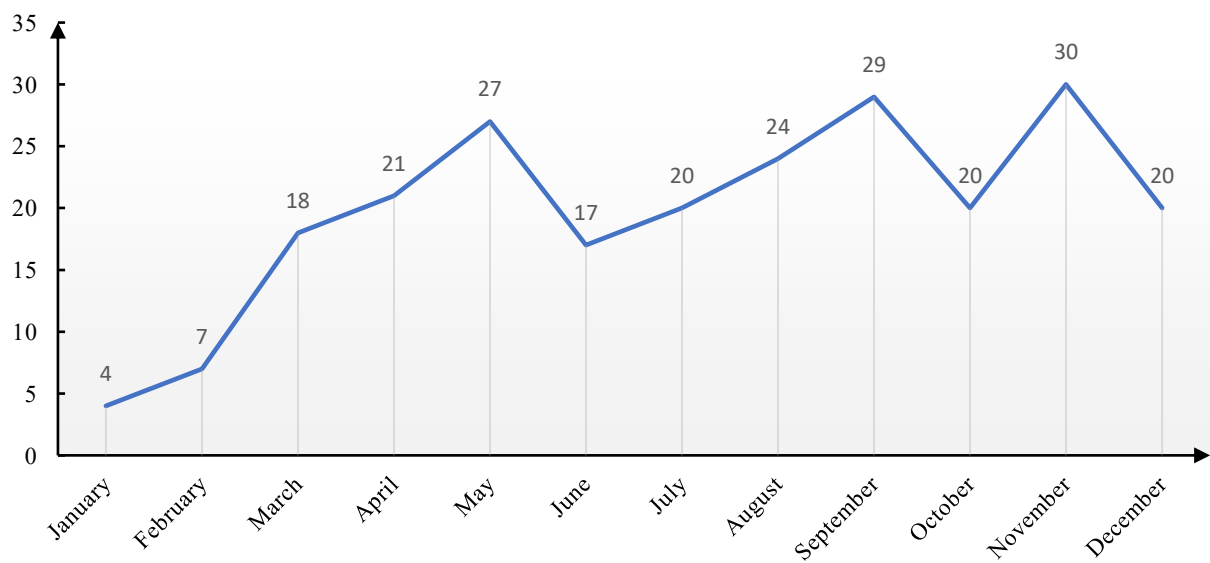
Figure 2 below presents the monthly distribution of outpatient consultations in the Yagoua Health District. It shows that during July, August, and September — which correspond to the flood period — the figures were 4,368, 3,902, and 3,274, respectively. A clear increase can be observed starting in July compared to the previous months (2,692 in June), reaching a peak in July, followed by a slight decrease in August and September, then a rebound in October with 3,826 consultations. From November (2,496) and December (2,689), there is a progressive decrease in the number of consultations, which may reflect a return to normal or a seasonal drop in health facility attendance.

183



184 **Figure 2: Number of outpatient consultations per month in the Yagoua Health District**

185 Figure 3 below presents the monthly distribution of the number of deaths recorded in the Yagoua
186 Health District in 2024. Data analysis reveals three peaks in mortality during the year, observed in May (27
187 deaths), September (29 deaths), and November (30 deaths). Moreover, by comparing the data from June —
188 before the floods — to those from August, corresponding to the peak of the critical period, we observe an
189 increase of about 15% in hospital deaths, suggesting a probable impact of the floods on mortality.



190

191

Figure 3: Number of deaths per month in the Yagoua Health District

Figure 4 below shows the monthly distribution of hospitalized patients in the Yagoua Health District in 2024. During July, August, and September — the flood period — the number of hospitalizations was 1,082, 1,150, and 1,056, respectively. Compared to the previous months, where hospitalizations ranged between 538 (in February) and 897 (in May), a clear rise is observed starting in July, with a first peak in August (1,150 hospitalizations), estimating an increase of around 38% during the flood peak. A second, more pronounced peak was reached in October with 1,369 hospitalizations, the highest level of the year.

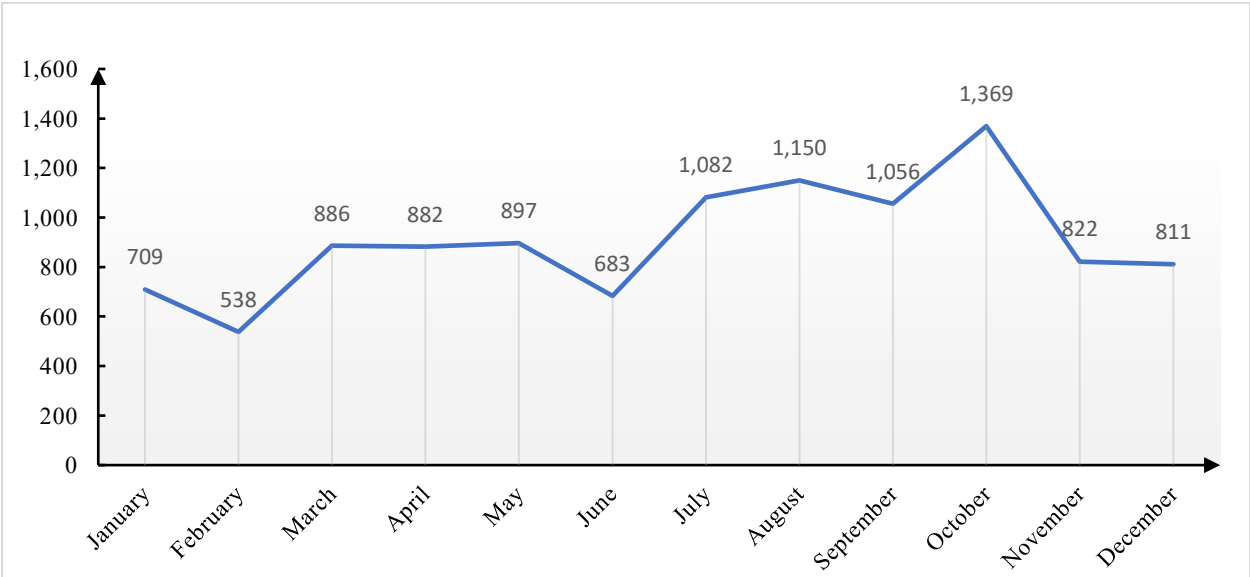


Figure 4: Number of hospitalized patients per month in the Yagoua Health District

Figure 5 below presents the monthly distribution of cases of severe acute malnutrition among children admitted in the Yagoua Health District in 2024. During July, August, and September — the flood period — the number of cases was 130, 164, and 152 respectively. August recorded the highest number of the year with 164 cases. This period stands out with a marked increase of approximately 51.8% compared to the previous months, particularly June, which recorded 79 cases.

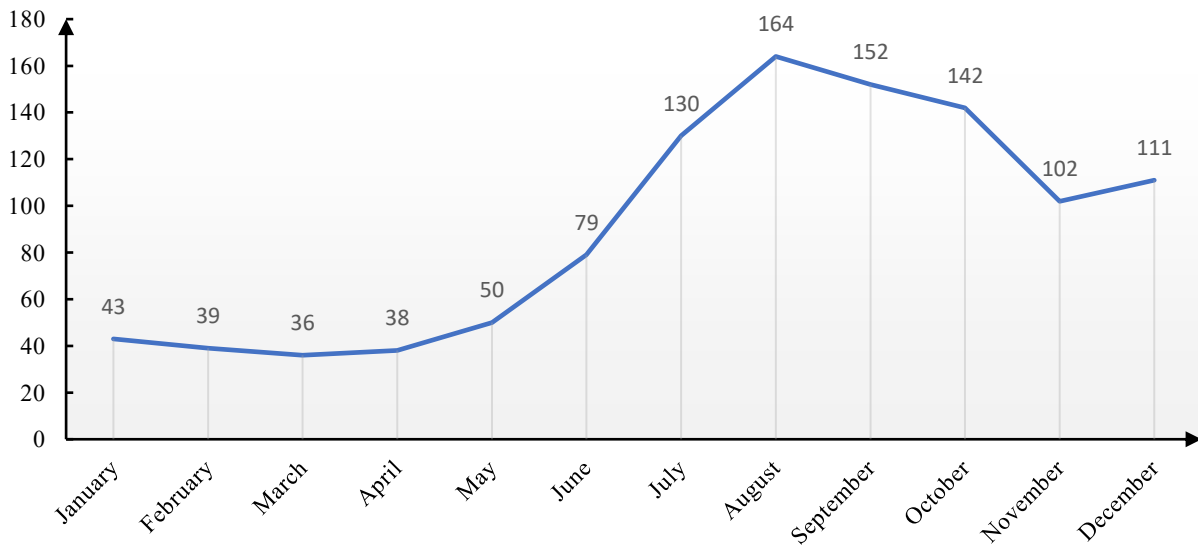


Figure 5: Number of severe acute malnutrition cases admitted per month in the Yagoua Health District

Figure 6 illustrates the monthly variation in the number of births recorded in the community in the Yagoua Health District during 2024. The data indicate that during July, August, and September — the flood period — the number of community births was 112, 161, and 101 respectively. Two major peaks were observed during the year: the first in April with 153 births, and the second, more significant, in August with 161 births, the highest figure of the year. The August peak represents an increase of approximately 48.44% compared to June, suggesting a possible link with the inaccessibility of health facilities during the floods.

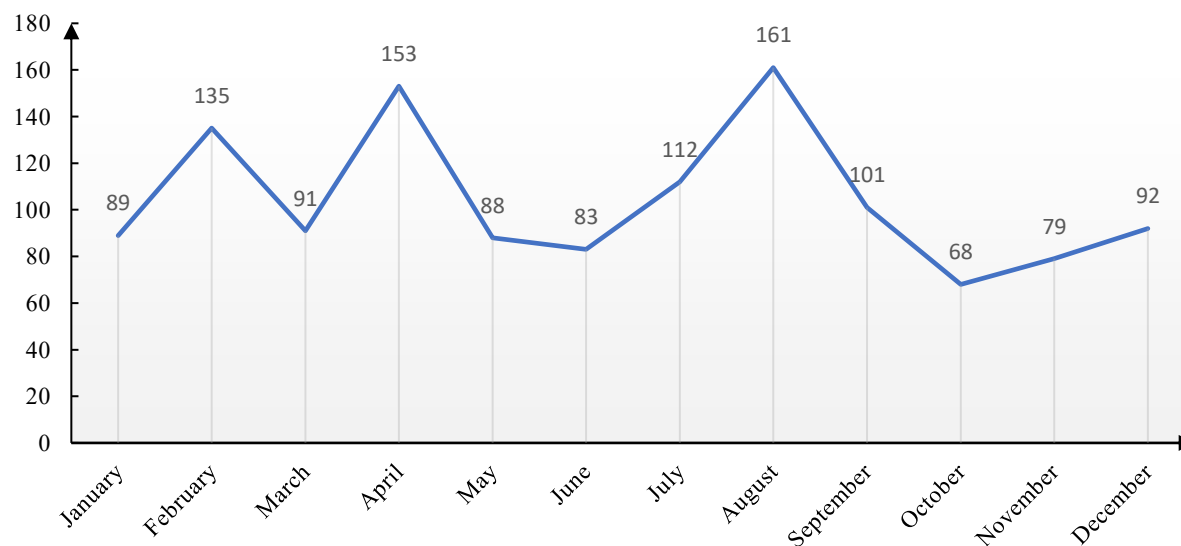


Figure 6: Number of community-based births per month in the Yagoua Health District

Figure 7 presents the monthly distribution of simple malaria cases confirmed by community health workers (CHWs) using rapid diagnostic tests (RDTs) in the Yagoua Health District. During July, August, and September, the number of cases recorded was 1,151, 2,742, and 2,881 respectively. A clear increase in the curve appears from July, with a doubling of cases compared to June (613 cases). Comparing June to August — the flood peak — there was a marked increase of around 77.6%. September recorded the annual peak, with a total of 2,881 confirmed simple malaria cases.

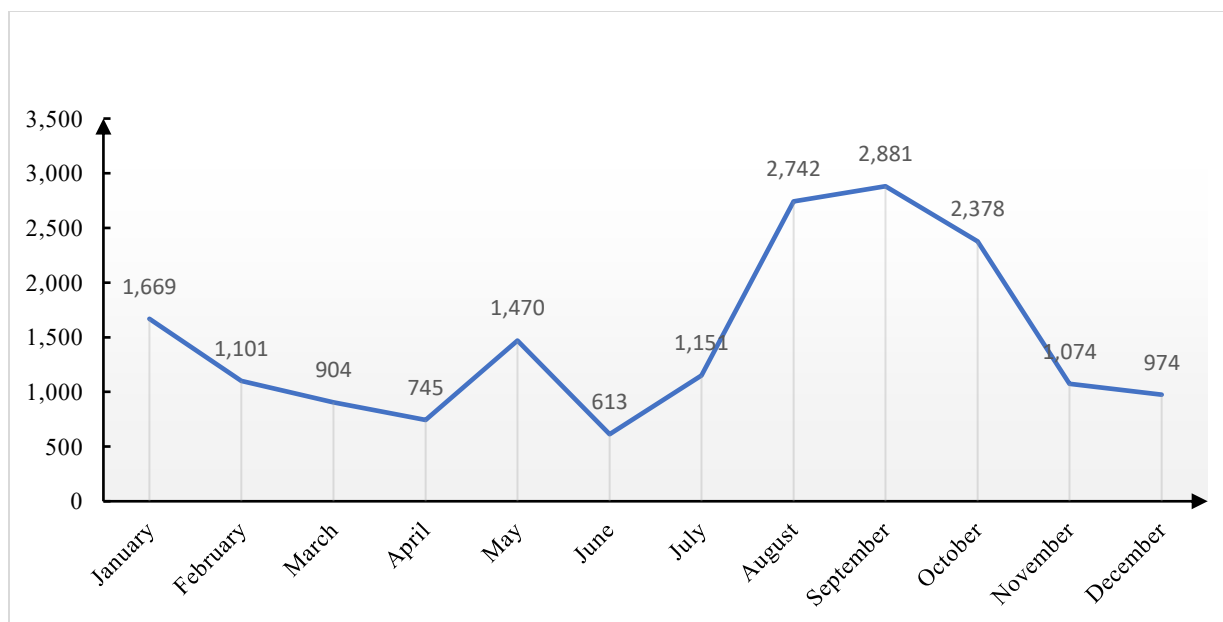


Figure 7: Number of simple malaria cases confirmed by CHWs using RDTs in the Yagoua Health District

Figure 8 below presents the monthly distribution of the number of HIV patients on antiretroviral therapy (ART) in the Yagoua Health District. During July, August, and September, the figures were 2,526, 2,531, and 2,570, respectively. We can observe an increase and stabilization of the active cohort throughout the flood period, despite potential disruptions caused by the floods.

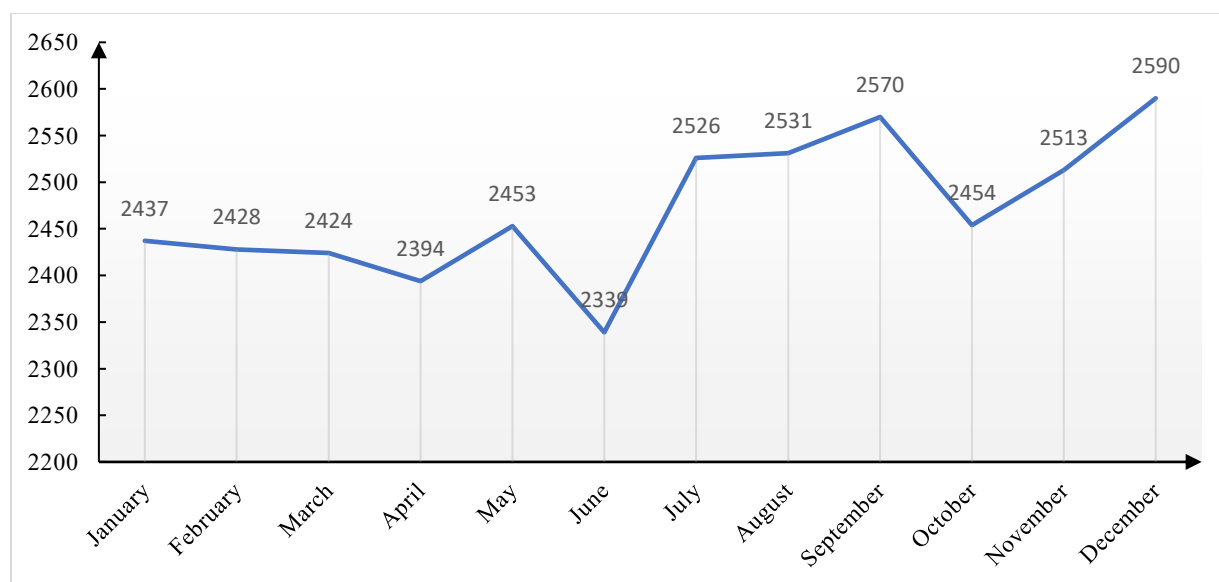


Figure 8: Active ART cohort per month in the Yagoua Health District

2- Group Differences Analysis Using the Kruskal-Walli's test

Table 1 : Group Differences Analysis Using the Kruskal-Walli's test

Kruskal-Wallis			
	χ^2	df	p-value
Number of severe acute malnutrition cases admitted per month	3.289	2	0.193
Number of children who received the Penta 1 vaccine during the month	1.689	2	0.430
Number of community-based births per month	5.600	2	0.061
Number of outpatient consultations per month	2.756	2	0.252
Number of hospitalized patients per month	5.422	2	0.066
Number of deaths per month	1.422	2	0.491
Number of simple malaria cases confirmed by CHWs using RDTs	4.356	2	0.113
Active ART cohort	3.200	2	0.202

The Kruskal–Walli’s test conducted across the flood-period months over the three study years (2023, 2024, and 2025) did not reveal statistically significant differences for any of the assessed service indicators (all p -values > 0.05). However, the number of community births per month ($p = 0.061$) and the number of hospitalized patients per month ($p = 0.066$) showed values close to the significance threshold, suggesting a possible trend toward variation across years.

Discussion

This study made it possible to analyze the evolution of several healthcare utilization indicators in the Yagoua health district during the flood period. The results highlight significant trends, with notable monthly variations in case numbers and healthcare access. These findings underscore the importance of examining the impact of floods on the health system, particularly at the level of affected districts.

Number of Children Who Received the Penta 1 Vaccine

The results of this study reveal a notable decrease in the number of children who received the Penta 1 vaccine during the flood period. This decline suggests a temporary disruption in vaccination coverage, likely linked to difficulties in accessing health services, the mobility of displaced populations, and logistical disorganization—particularly concerning the cold chain. A partial recovery of vaccination activities was observed after the critical period, reflecting a relative catch-up. Similar studies conducted in other regions of Cameroon and in Pakistan have also documented a reduction in vaccination coverage in crisis contexts, attributable to the destruction of health infrastructure, supply chain disruptions, and reduced accessibility of services for affected populations (Ali & Hamid, 2022).

Number of Outpatient Consultations

In this study, an increase in the number of outpatient consultations was observed during the flood period. This trend could be explained by the emergence of diseases directly or indirectly related to the floods, such as physical injuries and infectious diseases (Yang et al., 2024). Moreover, the deterioration or interruption of WASH (water, sanitation, and hygiene) services, despite the setup of temporary shelter facilities, may have favored the emergence and spread of certain infections (Paterson et al., 2018). Previous studies have also shown that floods can overload health facilities due to an increase in gastrointestinal diseases and other waterborne conditions (Saulnier et al., 2018).

Number of Deaths

The peak in mortality observed in September coincides with the flood period, suggesting a possible correlation between natural disasters and increased mortality. Previous studies have also reported a rise in deaths during crisis periods, often linked to the overloading of health services and the deterioration of living conditions (Yan et al., 2020; Yang et al., 2023).

Number of Hospitalized Patients

The mortality peak observed in September, which coincides with the end of the flood period, may reflect the cumulative effects of both direct consequences (such as injuries, drowning, and infections) and indirect consequences (such as disrupted health services and limited access to care) of this disaster on public health. This observation is supported by a study conducted in Vietnam by Phung et al. in 2021, which found an increase in hospitalizations in the weeks following a natural disaster. This trend suggests heightened pressure on health facilities during the flood period, likely linked to a surge in infectious diseases requiring hospitalization. Indeed, Phung et al. reported a relative hospitalization risk of 1.15 [1.03–1.29] in the first four weeks after a flood (Phung et al., 2021). Similarly, a study conducted in the United States by Deng in 2022 revealed an increased risk of hospitalization within 14 days following such climatic events (Deng et al., 2022).

Number of Cases of Severe Acute Malnutrition in Admitted Children

The spike in malnutrition cases coincides with the flood period, suggesting a deterioration in nutritional conditions due to the disruption of food systems, loss of livelihoods, and increased vulnerability among children under five in a context already marked by high malnutrition prevalence and rising food prices. This interpretation is supported by the World Food Programme report, which describes the scale of the floods that affected over 400,000 people in Cameroon and their impact on food security (WFP, 2024). However, this trend was not observed in the short term in some studies conducted in other contexts. For example, research by Rodriguez-Llanes in the Orissa district of India, conducted on similar populations but at different periods, did not identify an immediate increase in acute malnutrition after floods. However, their results showed an increased risk of chronic malnutrition and undernutrition two months after the event (Rodriguez-Llanes et al., 2011), as well as a rise in severe acute malnutrition cases one year after the floods, linked to crop destruction and lasting disruption of food supply chains (Rodriguez-Llanes et al., 2016).

Number of Community-Based Births

The results of this study revealed an increase in the number of community-based births during the flood period. This trend may be explained by a rise in deliveries occurring outside health facilities, due to

the physical inaccessibility of care centers during this period. Indeed, natural disasters such as floods are likely to disrupt the organization and accessibility of healthcare services, forcing many women to give birth at home or within the community. A recent study conducted in Cameroon in 2024 on structural barriers to accessing maternal health services found that crises, whether security-related or environmental, as well as the interruption of medical transport systems, are major risk factors associated with the increase in community-based deliveries (Harsono et al., 2024).

Number of Confirmed Simple Malaria Cases by CHWs Using RDTs

The number of simple malaria cases diagnosed by Community Health Workers (CHWs) in community settings rose significantly during the flood period, as revealed by this study. This trend is consistent with observations reported in other contexts. For instance, studies conducted in China, Sudan, and Uganda respectively reported an increased risk of malaria incidence in the first 11 weeks after flooding, on the 27th day following the disaster, and throughout the year after the event (Boyce et al., 2016; Ding et al., 2014; Elsanousi et al., 2018). These findings highlight the favorable environment for malaria vector proliferation created by floods, particularly through the accumulation of stagnant water conducive to mosquito breeding (Mwachui et al., 2015).

Number of People on Antiretroviral Treatment (ART)

The results of this study revealed an increase with very little variation in the number of patients on antiretroviral treatment (ART) during the flood period. This stability in the active treatment cohort suggests that differentiated care strategies implemented, particularly multi-month dispensing of ART, played a key role in maintaining continuity of care despite the disruptions caused by the natural disaster (Ministère de la Santé Publique du Cameroun, Guide Opérationnel de la Prestation des Services Différenciés du VIH, 2021). Similarly, some studies have shown that adopting differentiated care models strengthens health system resilience during crises by facilitating access to and adherence to ART, even in humanitarian settings (Decroo et al., 2013; Roy et al., 2019).

Kruskal-Wallis's Analysis

Although no statistically significant differences were observed across the three years for all health indicators, this finding should be interpreted with caution. The analytical approach was based on only three months of data per year, resulting in a small sample size and, consequently, limited statistical power. This constraint is common in disaster research, where defining affected populations and obtaining reliable pre-disaster data can be challenging, thereby complicating causal inference (Dorn et al., 2006). Studies

conducted in emergency or disaster contexts frequently encounter methodological limitations, as traditional controlled designs are often not feasible. As a result, many analyses rely on descriptive or observational approaches that may struggle to establish clear causal relationships (*Koenig and Schultz's Disaster Medicine: Comprehensive Principles and Practices*, 2016; Stratton, 2019).

In this context, some indicators, particularly the number of Community-Based Births and the number of Hospitalized Patients per month, produced p-values close to the threshold of statistical significance, suggesting a possible operational impact during the flood period. These trends may not have reached statistical significance due to the limited sample size and the resulting low statistical power. Indeed, insufficient power can lead to non-significant results even when real differences exist, especially in disaster-related analyses where effects may be moderate but operationally important (Hetherington et al., 2021).

Flood events are widely recognized as major disruptors of healthcare infrastructure and access to medical services, particularly in rural and resource-constrained settings (Pappas et al., 2024). They can create substantial geographical barriers, isolating communities, limiting physical access to health facilities, and interrupting supply chains for medicines, referrals, and emergency services (Mroz et al., 2023). Evidence from similar contexts has shown that seasonal flooding can significantly reduce women's access to essential maternal health services, including facility-based deliveries and emergency obstetric care, thereby increasing the risk of morbidity and mortality (Mroz et al., 2023).

Therefore, the downward trends observed in institutional deliveries and hospitalizations during the flood period, even in the absence of statistical significance, likely reflect real operational disruptions in healthcare access and service provision. These findings highlight the vulnerability of rural health systems to environmental shocks and underscore the need for targeted preparedness and resilience strategies. Future research based on larger sample sizes and longer observation periods would be necessary to more precisely quantify these effects and strengthen the evidence base.

Study Limitations

This study has several limitations that should be considered when interpreting the results. First, as a descriptive study, it does not allow for the establishment of causal relationships between the floods and the observed variations in health indicators. Furthermore, the study does not account for potential underreporting bias, which may have affected the accuracy and completeness of the reported data. Potential underreporting bias during the flood period may have affected data accuracy, facility disruptions likely led to incomplete recording of consultations, hospitalizations, and deaths, which would underestimate the true

impact. The direction of this bias is toward the null, meaning our findings may represent a conservative estimate of flood-related disruption. In addition, the absence of a control group limits the ability to directly compare the health impacts of the floods with non-crisis periods.

Moreover, the statistical analysis was based on the Kruskal–Walli’s test using a small number of monthly observations, which may have limited the statistical power to detect significant differences between years. The use of aggregated monthly data may also have masked short-term fluctuations within the flood period. As a result, some real operational effects of the floods may not have reached statistical significance despite observable trends in the data.

Conclusion and Recommendations

In conclusion, this study highlighted significant changes in several health indicators in the Yagoua health district during the flood period, underscoring the direct impact of these disasters on healthcare access and population health. The observed variations, particularly the increase in consultations and flood-related pathologies, illustrate the challenges faced by health systems in areas affected by natural disasters.

It is essential to strengthen crisis preparedness in these regions by improving healthcare infrastructure, training health professionals to respond effectively to emergencies, and implementing adapted crisis management strategies. It is also recommended to conduct more in-depth studies on the impact of floods on public health, particularly through longitudinal research and the use of control groups, to better understand the long-term effects and identify best practices to mitigate these impacts.

Declarations

Funding Statement

The authors did not receive any funding for the conduct of the research, writing, or publication of this article.

Data Availability

The datasets analyzed in this study consist of fully anonymized and aggregated national surveillance data obtained from the DHIS2 system under the governance of the Department for Disease, Epidemic and Pandemic Control, Ministry of Public Health, Cameroon. The data are owned by the Ministry of Public Health and are accessible to authorized health system stakeholders as part of their official public health duties. While the aggregated, non-identifiable data summaries supporting this study's findings are available from the corresponding author upon reasonable request, the raw underlying surveillance datasets

cannot be shared publicly due to national data governance policies. Requests for access to raw data by third parties must be submitted formally to the competent health authorities at the Ministry of Public Health, Cameroon.

References

- (DMN), D. d. l. m. n. d. C. (2024). *les données officielles sur les précipitations par région au Cameroun*. Sous-Direction des Applications Météorologiques. Retrieved 14/04 from <https://meteocameroon.gov.cm/>
- Abbott, P. L. (2006). *Natural disasters* (Vol. 5). Boston : McGraw-Hill Higher Education.
- Adams, A. G. (2008). *Perrinial flooding in the Accra metropolis: the human factor* University of science and technology Kumasi-Ghana]. SCRIBD.
- Alderman, K., Turner, L. R., & Tong, S. (2012). Floods and human health: a systematic review. *Environ Int*, 47, 37-47. <https://doi.org/10.1016/j.envint.2012.06.003>
- Ali, I., & Hamid, S. (2022). Implications of COVID-19 and "super floods" for routine vaccination in Pakistan: The reemergence of vaccine preventable-diseases such as polio and measles. *Hum Vaccin Immunother*, 18(7), 2154099. <https://doi.org/10.1080/21645515.2022.2154099>
- Allaire, M. (2018). Socio-economic impacts of flooding: A review of the empirical literature. *Water Security*, 3, 18-26. <https://doi.org/https://doi.org/10.1016/j.wasec.2018.09.002>
- Allan, R. P., & Soden, B. J. (2008). Atmospheric warming and the amplification of precipitation extremes. *Science*, 321(5895), 1481-1484. <https://doi.org/10.1126/science.1160787>
- Boyce, R., Reyes, R., Matte, M., Ntaro, M., Mulogo, E., Metlay, J. P., Band, L., & Siedner, M. J. (2016). Severe Flooding and Malaria Transmission in the Western Ugandan Highlands: Implications for Disease Control in an Era of Global Climate Change. *J Infect Dis*, 214(9), 1403-1410. <https://doi.org/10.1093/infdis/jiw363>
- Data, C. (2024). *climate Yagoua*. <https://fr.climate-data.org/>
- Decroo, T., Rasschaert, F., Telfer, B., Remartinez, D., Laga, M., & Ford, N. (2013). Community-based antiretroviral therapy programs can overcome barriers to retention of patients and decongest health services in sub-Saharan Africa: a systematic review. *International health*, 5, 169-179. <https://doi.org/10.1093/inthealth/ih016>
- Deng, X., Friedman, S., Ryan, I., Zhang, W., Dong, G., Rodriguez, H., Yu, F., Huang, W., Nair, A., Luo, G., & Lin, S. (2022). The independent and synergistic impacts of power outages and floods on hospital admissions for multiple diseases. *Sci Total Environ*, 828, 154305. <https://doi.org/10.1016/j.scitotenv.2022.154305>
- Ding, G., Gao, L., Li, X., Zhou, M., Liu, Q.-Y., Ren, H., & Jiang, B. (2014). A Mixed Method to Evaluate Burden of Malaria Due to Flooding and Waterlogging in Mengcheng County, China: A Case Study. *PloS one*, 9, e97520. <https://doi.org/10.1371/journal.pone.0097520>
- Dorn, T., Yzermans, C. J., Kerssens, J. J., Spreuwenberg, P. M., & van der Zee, J. (2006). Disaster and subsequent healthcare utilization: a longitudinal study among victims, their family members, and control subjects. *Med Care*, 44(6), 581-589. <https://doi.org/10.1097/01.mlr.0000215924.21326.37>
- Elsanousi, Y. E. A., Elmahi, A. S., Pereira, I., & Debacker, M. (2018). Impact of the 2013 Floods on the Incidence of Malaria in Almanagil Locality, Gezira State, Sudan. *PLoS Curr*, 10. <https://doi.org/10.1371/currents.dis.8267b8917b47bc12ff3a712fe4589fe1>

- Glago, F. (2021). Flood Disaster Hazards; Causes, Impacts and Management: A State-of-the-Art Review. In. <https://doi.org/10.5772/intechopen.95048>
- Harsono, A. A. H., Bond, C. L., Enah, C., Ngong, M. G., Kyeng, R. M., Wallace, E., Turan, J. M., Szychowski, J. M., Carlo, W. A., Ambe, L. N., Halle-Ekane, G., Muffih, P. T., Tita, A. T. N., & Budhwani, H. (2024). Structural barriers to maternity care in Cameroon: a qualitative study. *Reproductive Health*, 21(1), 108. <https://doi.org/10.1186/s12978-024-01834-w>
- Hetherington, E., Adhikari, K., Tomfohr-Madsen, L., Patten, S., & Metcalfe, A. (2021). Birth outcomes, pregnancy complications, and postpartum mental health after the 2013 Calgary flood: A difference in difference analysis. *PLoS One*, 16(2), e0246670. <https://doi.org/10.1371/journal.pone.0246670>
- Koenig and Schultz's Disaster Medicine: Comprehensive Principles and Practices. (2016). (K. L. Koenig & C. H. Schultz, Eds. 2 ed.). Cambridge University Press. <https://doi.org/DOI:10.1017/CBO9781139629317>
- Lorenzoni, N., Stühlinger, V., Stummer, H., & Raich, M. (2020). Long-Term Impact of Disasters on the Public Health System: A Multi-Case Analysis. *Int J Environ Res Public Health*, 17(17). <https://doi.org/10.3390/ijerph17176251>
- Mroz, E. J., Willis, T., Thomas, C., Janes, C., Singini, D., Njunga, M., & Smith, M. (2023). Impacts of seasonal flooding on geographical access to maternal healthcare in the Barotse Floodplain, Zambia. *Int J Health Geogr*, 22(1), 17. <https://doi.org/10.1186/s12942-023-00338-3>
- Mwachui, M. A., Crump, L., Hartskeerl, R., Zinsstag, J., & Hattendorf, J. (2015). Environmental and Behavioural Determinants of Leptospirosis Transmission: A Systematic Review. *PLoS Negl Trop Dis*, 9(9), e0003843. <https://doi.org/10.1371/journal.pntd.0003843>
- OCHA. (2024a, 16 April 2024). Cameroon 2024 Humanitarian Response Plan. <https://www.unocha.org/publications/report/cameroon/cameroon-2024-humanitarian-response-plan-issued-april-2024>
- OCHA. (2024b, 20 Sept 2024). Cameroun : Extrême-Nord - Aperçu des inondations. 4.
- Pappas, A., Kovats, S., & Ranganathan, M. (2024). Extreme weather events and maternal health in low-income and middle-income countries: a scoping review. *BMJ Open*, 14(6), e079361. <https://doi.org/10.1136/bmjopen-2023-079361>
- Paterson, D. L., Wright, H., & Harris, P. N. A. (2018). Health Risks of Flood Disasters. *Clin Infect Dis*, 67(9), 1450-1454. <https://doi.org/10.1093/cid/ciy227>
- Phung, D. T., Warren, J. L., Chu, C. M., & Dubrow, R. (2021). Relationship between flood severity and risk of hospitalisation in the Mekong River Delta of Vietnam. *Occup Environ Med*, 78(9), 676-678. <https://doi.org/10.1136/oemed-2021-107768>
- Rodriguez-Llanes, J. M., Ranjan-Dash, S., Degomme, O., Mukhopadhyay, A., & Guha-Sapir, D. (2011). Child malnutrition and recurrent flooding in rural eastern India: a community-based survey. *BMJ Open*, 1(2), e000109. <https://doi.org/10.1136/bmjopen-2011-000109>
- Rodriguez-Llanes, J. M., Ranjan-Dash, S., Mukhopadhyay, A., & Guha-Sapir, D. (2016). Flood-Exposure is Associated with Higher Prevalence of Child Undernutrition in Rural Eastern India. *Int J Environ Res Public Health*, 13(2), 210. <https://doi.org/10.3390/ijerph13020210>
- Roy, M., Bolton Moore, C., Sikazwe, I., & Holmes, C. B. (2019). A Review of Differentiated Service Delivery for HIV Treatment: Effectiveness, Mechanisms, Targeting, and Scale. *Curr HIV/AIDS Rep*, 16(4), 324-334. <https://doi.org/10.1007/s11904-019-00454-5>

- Saulnier, D. D., Hanson, C., Ir, P., Mölsted Alvesson, H., & von Schreeb, J. (2018). The Effect of Seasonal Floods on Health: Analysis of Six Years of National Health Data and Flood Maps. *Int J Environ Res Public Health*, 15(4). <https://doi.org/10.3390/ijerph15040665>
- Stratton, S. J. (2019). Data Sampling Strategies for Disaster and Emergency Health Research. *Prehosp Disaster Med*, 34(3), 227-229. <https://doi.org/10.1017/s1049023x19004412>
- Tabassum, S., Kalsoom, T., Zaheer, Z., Naeem, A., Afifi, A., & Ohadi, L. (2023). Reflections on the surge in malaria cases after unprecedented flooding in Pakistan-A commentary. *Health Sci Rep*, 6(10), e1620. <https://doi.org/10.1002/hsr2.1620>
- WFP. (2024, 12/11/2024). WFP responds to severe flooding in Cameroon that affects over 400,000 people.
- WHO. (2020). *Floods*. Retrieved 19 /04 from <https://www.who.int/health-topics/floods#tab=tab>
- Yan, M., Wilson, A., Peel, J. L., Magzamen, S., Sun, Q., Li, T., & Anderson, G. B. (2020). Community-wide Mortality Rates in Beijing, China, During the July 2012 Flood Compared with Unexposed Periods. *Epidemiology*, 31(3). https://journals.lww.com/epidem/fulltext/2020/05000/community_wide_mortality_rates_in_beijing_china,2.aspx
- Yang, Z., Huang, W., McKenzie, J., Xu, R., Yu, P., Ye, T., Wen, B., Gasparrini, A., Armstrong, B., Tong, S., Lavigne, E., Madureira, J., Kysely, J., Guo, Y., Li, S., & Carrasco-Escobar, G. (2023). Mortality risks associated with floods in 761 communities worldwide: time series study. *BMJ*, 383, e075081. <https://doi.org/10.1136/bmj-2023-075081>
- Yang, Z., Huang, W., McKenzie, J. E., Yu, P., Ju, K., Wu, Y., Wen, B., Guo, Y., & Li, S. (2024). Mortality and morbidity risks associated with floods: A systematic review and meta-analysis. *Environmental Research*, 263, 120263. <https://doi.org/https://doi.org/10.1016/j.envres.2024.120263>
- Zhang, W., Villarini, G., Vecchi, G. A., & Smith, J. A. (2018). Urbanization exacerbated the rainfall and flooding caused by hurricane Harvey in Houston. *Nature*, 563(7731), 384-388. <https://doi.org/10.1038/s41586-018-0676-z>