

Impact of Climate Change-Induced Flooding Water Related Diseases and Malnutrition in Borno State, Nigeria: A Public Health Crisis

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ABSTRACT: Climate change-induced flooding has caused public health crises in Borno State, Nigeria, which influence the increase of waterborne diseases and malnutrition. Flooding disrupts water and sanitation systems, creating breeding grounds for waterborne diseases such as cholera, malaria, and diarrheal illnesses. The displacement of communities and destruction of agricultural infrastructure due to flooding further increase food insecurity, leading to malnutrition. This paper examines the interplay between flooding, waterborne diseases, and malnutrition in Borno State, highlighting the urgent need for climate adaptation strategies and strengthened healthcare systems to mitigate these public health challenges. Additionally, it highlights the double burden of conflict and climate change where ongoing conflicts impede efforts to mitigate and adapt to climate change. Finally, this paper outlines the socio-economic impacts of flooding and proposes interventions to mitigate the effects of flooding.

KEYWORDS: Climate change, flooding, waterborne diseases, malnutrition, Borno State, Nigeria, public health, cholera, food insecurity, adaptation strategies

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Background

Climate change has become a global trend driven by the increasing temperature of the earth.^{1,2} Climate change is defined as long-term changes in the environmental temperature due to the accumulation of greenhouse gasses (GHGs) such as carbon dioxide, methane, and nitrous oxide in the atmosphere as a result of human activities therefore resulting in a global warming.^{3,4} However the United Nations defined climatic changes as a progressive changes in temperature and weather trends which may be natural or due to human events.⁵ African regions are not excluded from the tremendous effects of extreme temperature changes in the atmosphere causing challenging conditions such as flooding, droughts, heat waves, and wildfires.⁶ Although these climatic changes are seen firsthand in the environment, it has a direct impact on the well-being of dwellers within affected

regions contributing to a rise in nutritional deficiency, spread of diseases, and an increase in communicable diseases.^{1,7} Africa is most vulnerable to the effect of climate changes as it negatively impacts water supply, agriculture, health, and the environment making its population at risk of diseases and increased morbidity and mortality.^{7,8}

Borno, a north-eastern part of Nigeria is not left out in the menace imposed by changes in the climate therefore triggering insurgencies, human displacements, food scarcity.⁹ In September 2024, records show an incident of flooding in Borno which according to a report by ACAPS was influenced by heavy rainfall and the damage to the Dam infrastructure, as a result more than 200,000 people got affected by the flood, 30 death cases reported and 50 000 people becoming internally displaced.¹⁰ Prior to the flooding incident, Borno state had suffered from desertification



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and its residents especially mothers and children suffering from malnutrition for over 10 years due to climatic changes.¹⁰ Although, there had been an occurrence of spread of diseases like cholera and diphtheria mid 2024 in Nigeria, the flooding in Borno and other states affected by flood will increase the spread of infectious diseases and leading to an increment of burden to the already limited health facility within the community.

The severity of the flooding has led to a serious public health crisis exposing vulnerable persons such as children, pregnant women, nursing mothers, elderly, and people living with disabilities and chronic conditions to potential health challenges and even hardship.¹¹ Climate change is a pressing issue in Borno, Nigeria with the recent flooding that has increased the havoc of the current situation of things in Borno such as conflicts, education, health facility, agriculture, economy, and livelihood. This paper discusses climate change induced flooding and its influence on public health, reviewing existing interventions, socio-economic impacts, impact on waterborne diseases, nutrition, and food security and challenges and highlighting recommendations for intervening in the public health crisis.

Methods

The literature search for the paper titled *Impact of Climate Change-Induced Flooding, Waterborne Diseases, and Malnutrition in Borno State, Nigeria: A Public Health Crisis* involved a comprehensive and systematic review of relevant sources published from 2000 to 2024. The primary databases searched included PubMed, Scopus, Google Scholar, and Web of Science, focusing on studies that examine the intersection of climate change, flooding, waterborne diseases, and malnutrition in Sub-Saharan Africa, with an emphasis on Nigeria. Keywords such as “climate change,” “flooding,” “waterborne diseases,” “malnutrition,” and “Borno State” were used in various combinations to capture the breadth of available literature. Additional sources were identified through citation tracking of key articles and gray literature from relevant government and NGO reports, focusing on the impact of flooding on public health in Nigeria. The inclusion criteria prioritized studies that discussed climate-related disasters in the context of public health, with specific attention to vulnerable regions like Borno State. Studies that addressed the direct and indirect effects of flooding on the transmission of waterborne diseases such as cholera and dysentery, as well as the nutritional consequences in the affected populations, were particularly emphasized. After reviewing the literature, the selected studies provided a robust evidence base for understanding the scope of the public health crisis and the complex interactions between climate change, flooding, and disease outbreaks in Borno State.

Climate change and flooding in Borno State

Borno State, located in northeastern Nigeria, has experienced unprecedented levels of rainfall in recent years, resulting in

severe flooding.¹² The region is particularly vulnerable to the effects of climate change due to its arid and semi-arid environment, poor infrastructure, and ongoing conflicts. Floods have destroyed homes, displaced thousands of people, and disrupted agricultural activities, which are the main source of livelihood for the local population.¹² The state currently has over 70% of internally displaced persons (IDPs) living in overcrowded and poorly maintained camps, which has been further impacted by the floods. These camps, which lack adequate sanitation and clean water, become breeding grounds for infectious diseases, compounding the existing health crisis.¹²

Borno State is characterized by a distinct climate, with short rainy season between June to December and a long dry season with notably high temperatures between October and May.¹³ The hot season average temperatures often reach 39°C and 40°C while rainfall in the region is typically sporadic and of short duration, frequently followed by extended dry spells, making it highly unpredictable, and unreliable.¹⁴ The effects of global climate change are evident in the state with the alteration in precipitation patterns and increased temperature variability over the last few years which are linked to activities such as poor land use practices and deforestation. These alterations in precipitation patterns and temperature have led to extreme weather events such as intense rainfall, floods and drought.¹⁵

Historically, surface air temperatures in Borno State have shown an upward trend between the periods 1961 to 1990 and 1991 to 2020. However, between 1991 and 2020, temperatures increased slightly, ranging from 22.78°C in January to 33.07°C in April, as shown in Figure 1.¹⁶ The shift in precipitation patterns further illustrates the changing climate. From 1961 to 1990, precipitation during the months of April to October ranged from a low of 11.62 mm in April to a peak of 193.51 mm in August.¹⁶ These changes indicate a trend toward more intense rainfall, reflecting the broader impacts of global climate change on both temperature and precipitation in the region. In 2024, the consequences of this were seen in Borno State, where heavy rainfall between August and September caused widespread flooding. One of the significant factors contributing to the flooding was the collapse of the Alau Dam, which led to extensive infrastructure damage and the displacement of several households.¹¹

Climate and environmental contributors to flooding in Borno State

Flooding occurs when typically, dried land becomes submerged due to rainfall, overflowing rivers or dams. In Borno, heavy rainfall has been a significant climate change-driven factor contributing to flooding. Rising temperatures and increased evaporation has altered precipitation patterns over the years as shown in Figure 1. Consequently, intense rainfall occurring over short periods often overwhelms the drainage systems leading to flooding.¹⁷ Deforestation is another contributor to flooding, this occurs when the clearing of forests

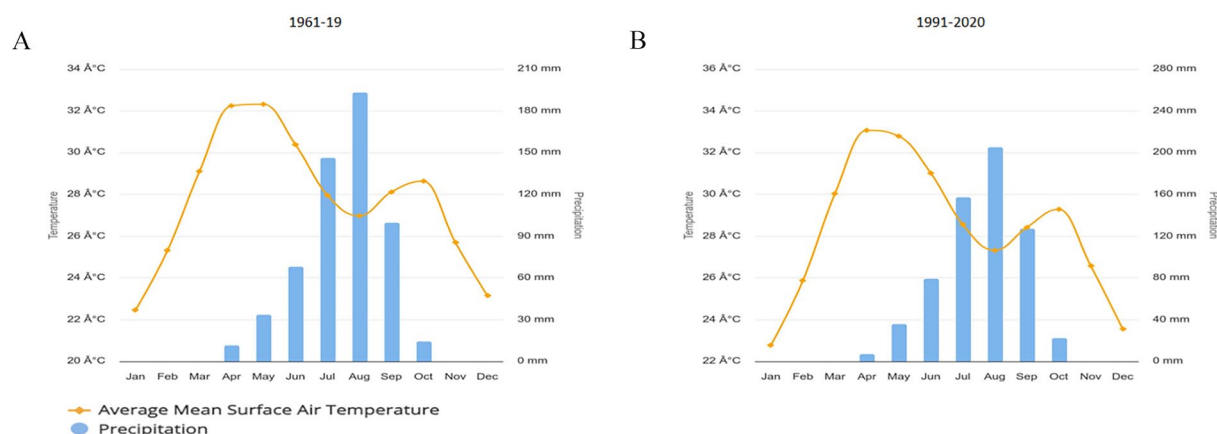


Figure 1. Monthly climatology of average mean surface air temperature and precipitation: (A) 1961 to 1990 and (B) 1991 to 2020.¹⁶

for agriculture, mining, and urbanization reduces the ability of the land to absorb rainwater resulting in increased surface runoff.^{18,19} Rivers and Dam overflow caused by heavy rainfall and blockage in water ways have also played a key role in recent flood events, such as the one in September 2024.¹⁹ Additionally, human activities such as housing development in water-logged areas, improper sewage disposal, constructions obstructing drainage channels and government negligence in expanding infrastructure to meet the needs of a growing population and migration, further intensify flooding risks.^{20,21}

Climate Change, Flooding, and Public Health in Borno State

The impacts of climate change (CC) have been experienced globally, especially in the tropics. These have triggered a wide variety of physical and biological changes across the world with negative effects on agriculture, humans, and the environment. It is therefore, important to note that while the vulnerability to CC impacts is higher in lower-middle- and low-income countries, particularly Africa, the readiness to improve resilience ranks very low in such countries.²² A recent report by World Bank for instance, shows that Nigeria is one of the top 10 of the most exposed countries to the effects of CC, with about 6% of its land area estimated to be exposed to extreme weather events.²³ Several incidences of environmental change in Nigeria include drought, flood, irregular rainfall pattern, deforestation, desert encroachment, and housing problems; and just like in India, Sudan, and other top vulnerable countries, these have significantly influenced land use and land cover, human health, and livelihoods in the country with little or no indication of appropriate adaptation plans.²⁴⁻²⁶ In the Northern areas of Nigeria, it is evident that they are highly vulnerable to climate change, with increasing flooding events exacerbating existing public health crises.²⁷

Meanwhile, the geographical location of the region, coupled with its socio-political instability and displacement of populations, heightens the risk of infectious disease outbreaks and malnutrition. The northeastern region of Nigeria, specifically

Borno State, faces escalating challenges linked to climate change, with flooding being a particularly acute issue.^{28,29} Climate change has brought unprecedented rainfall to Borno State, intensifying flooding incidents in an already fragile environment. The region is particularly vulnerable due to its arid and semi-arid climate, which typically does not have the infrastructure to manage significant water flow. Heavy rains overwhelm the drainage systems, leading to frequent flash floods that affect both urban and rural communities. A GIS analysis shows that over 30 IDP camps around Maiduguri are situated in flood-prone areas as shown in Figure 2, putting thousands at risk of displacement and disease.³⁰ The natural flow of water in these areas, compounded by deforestation and soil degradation, further increases the likelihood of flood-induced emergencies.

Aside from the impact of climate change, massive displacements in other towns, leading to forced migration to Maiduguri, have also affected the geography of the city, causing it to lose surface soil. Maiduguri is about 167km² in size. The total area under assessment for flood risk is about 209.27km² wide in a landmass area encompassing the Maiduguri metropolis and the areas surrounding the town. About 193km² of this total landmass is vulnerable to flood at different levels; 88.3km² of the total landmass is considered a high-risk area. And over 9500 IDPs are vulnerable to flooding in these high-risk places. An estimated 17153 IDPs might be susceptible to the hazard despite living in low-risk areas. The flood risk analysis also shows that about 52.17km² of the landmass within the Maiduguri area is considered to have low vulnerability to flood, 76.79km² of the area falls under vulnerable, while about 11.46km² is highly vulnerable. A 5-year analysis of some of the IDP camps and places around Maiduguri shows growth in physical structures, even around IDP camps. These growths put a strain on the topography of the various areas where the IDP camps are situated, making them more vulnerable during flooding as shown in Figures 3 and 4.

Flooding creates an ideal environment for the spread of diseases such as cholera, typhoid, and malaria. The report by HumAngle on the August 2022 cholera outbreak indicates



📷 A flooded Sharwari 5 IDP camp in Maiduguri. Photo credit: NRC/Catriona Loughran

Figure 2. Flooded Sharwari IDP camp in Maiduguri (Photo Credit: NRC/Catriona Loughran).

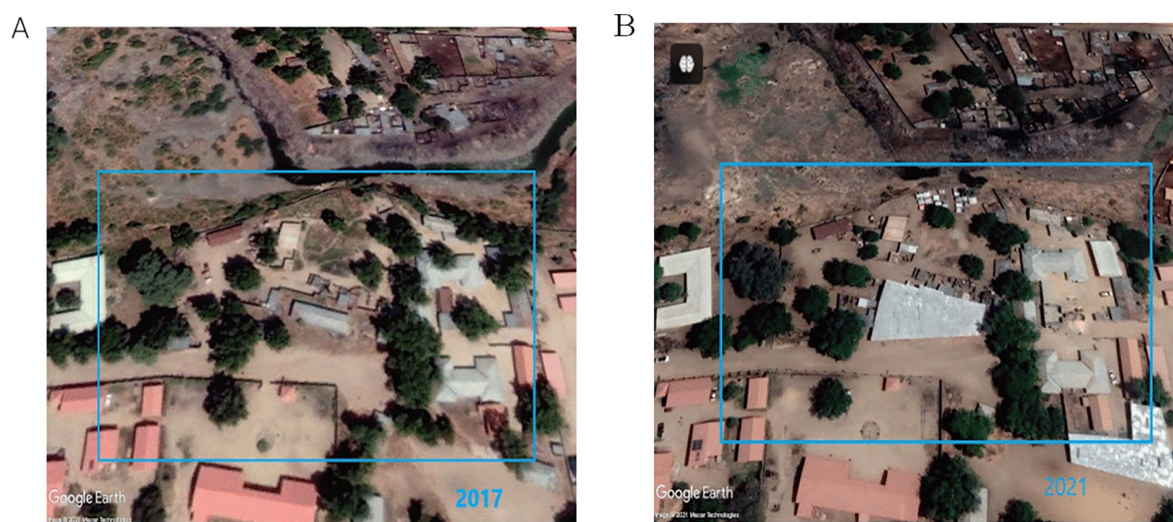


Figure 3. Gif of Askira Street IDP Camp: Timelapse of one of the most vulnerable flood-prone IDP Camps in Maiduguri: (A) 2017 and (B) 2021.³⁰ Credit: Mansir Muhammed/Google earth pro/HumAngle.

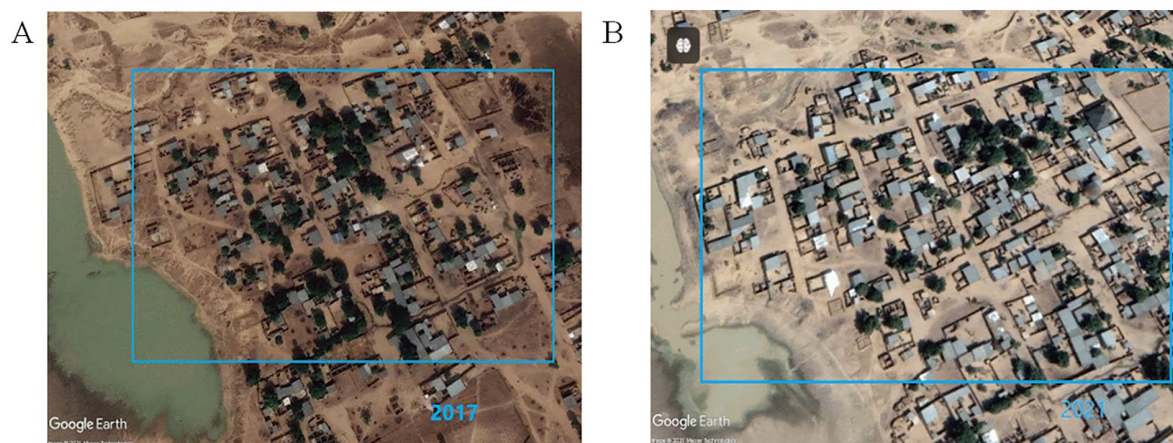


Figure 4. Gif of Fulatari Farin Ruwa IDP camp: Timelapse of one of the most vulnerable flood-prone IDP Camps in Maiduguri: (A) 2017 and (B) 2021.³¹ Credit: Mansir Muhammed/Google earth pro/HumAngle.



Figure 5. Farmlands destroyed by flooding in Borno community.
Credit: Usman Abba Zanna/HumAngle.

that the stagnant water, combined with poor sanitation in IDP camps, significantly contributed to the rapid transmission of cholera. Furthermore, these conditions also exacerbate the prevalence of vector-borne diseases like malaria, which thrive in floodwater left unchecked.³¹ In Borno State, most residents depend on subsistence farming, which is vulnerable to the damaging effects of climate change-induced floods as shown in Figure 5.

As the flood waters in Maiduguri, the capital of Borno State, northeastern Nigeria, begin to recede, the submerged city is facing the effects. A significant portion of the state capital has been damaged, leaving local business owners to face considerable financial and emotional losses. However, traders have started reopening their shops for business activities. Humangle visited the general area of the post office to gauge the mood for businesses that have been underwater for more than a week and to assess the impact on their investments. The situation evoked nothing but nostalgic emotions.³⁰ In some of the reviewed locations, the soil area has become more shallow and human structures are slowly replacing natural breakers like trees, which can act as support systems during and against some of these disasters. Despite these assessments, there is little to no effort on the part of the government to either avert these disasters, to make evacuation plans for them, or to prepare the IDPs in case of such emergencies.³¹

Impact on waterborne diseases

Flooding significantly increases the risk of waterborne and vector-borne diseases in Borno State. Floodwaters often contaminate drinking water sources, leading to the rapid spread of cholera and other diarrheal diseases. The unsanitary conditions in camps and affected communities make it difficult to control these outbreaks. In recent years, Borno has seen numerous cholera outbreaks following floods.³² A small intestine infection known as cholera causes acute, severe diarrhea that can be fatal and extremely virulent. There have been occasional outbreaks of cholera in the past, the first of which was documented in 1881.³³ As a result of rising urbanization, poor sanitation, and a lack of access to clean water, diarrhea has become a major

health concern in developing nations, accounting for 94% of the 4 billion cases of diarrhea that occur worldwide each year.³⁴

Diarrhea also kills 1.3 million children.³⁵ One of the deadliest endemic diseases, cholera primarily strikes rural and urban areas with poor sanitation and limited access to clean water. A total of 7485 cases of cholera and 319 associated deaths were reported as of October 12 in the northeastern states of Borno, Adamawa, and Yobe alone.³⁶ As rains are predicted to continue for several weeks, humanitarian needs are also anticipated to increase. Since the flooding incident in Nigeria, over 1.3 million people have been displaced and over 200 000 houses have either been partially or fully damaged.³⁶ Over 600 people have lost their lives as a result of the floods, and cases of diarrhea and water-borne diseases, respiratory infections, and skin diseases have already begun to rise.^{36,37} Before the flooding, the number of children suffering from acute watery diarrhea and malaria had begun to rise, and since the floods, we have seen some exhibiting clinical indications of cholera.³⁸

The likelihood of water-borne illnesses like cholera spreading is increased by flooding.³⁹ In addition to cholera, diseases like dengue, malaria, and hepatitis B, acute malnutrition has also been linked to 1.6 million children, increasing their vulnerability to infections, respiratory distress, and diarrheal illnesses in Nigeria.⁴⁰ In addition, the economy of Nigeria has suffered greatly as a result of the infrastructure being destroyed, rendering services like healthcare nearly inaccessible to the general people for illnesses like cholera.⁴¹

Impact on nutrition and food security

According to the World Bank, the prevalence of moderate and severe food insecurity combined in the Nigerian population in 2021 was 69.7%, while the prevalence of severe food insecurity was 21.3%. This is a jump from previous records of 34.7% and 11% respectively in 2015.⁴² This prevalence continues to increase, and the North-East and North-West regions, including Borno state, are mostly affected.⁴³ The food security situation in Borno state is exceptionally high as 9 of 10 (88%) households in Jere Local Government Area (LGA) experienced food insecurity in 2023.⁴⁴

Similarly, the prevalence of undernourishment in Nigeria increased from 9% in 2011 to 16% in 2021.⁴⁵ The prevalence of undernourishment is the percentage of the population whose habitual food consumption does not meet the dietary energy needed to lead a healthy life.⁴⁶ In 2022, over 1.3 million children under 5 years were faced with the threat of malnutrition in North East Nigeria including Borno state, and this prevalence peaks during the rainy and lean (post-harvest) seasons.⁴⁷ In 2023, FHI 360 reported a 160% increase in the number of children admitted to their facilities needing treatment for moderate and severe wasting.⁴⁸ Similarly, Doctors Without Borders admitted twice as many severely malnourished children with complications in April 2024 than in April 2023.⁴⁷ These

worsening situations of food insecurity and malnutrition in Borno were attributed to the loss of arable land consequent to decades of the Boko Haram insurgency and past flooding events and underscores the need for continued humanitarian support.⁴⁸⁻⁵²

In a repetitive pattern of the events from past years, the 2024 flooding is beginning to have a devastating impact on food security, a major driver of malnutrition in Borno State. Agriculture, the mainstay of the economy,⁵³ has been severely disrupted by the floods.⁵⁴⁻⁵⁶ Crops have been washed away, livestock lost, and food supplies contaminated.^{57,58} For a region that was already facing food shortages due to conflict, the floods have worsened an already dire situation. This has specifically impacted food and nutrition security in the following ways:

1. **Food Shortages:** With fields submerged in water and agricultural productivity drastically reduced, food availability has plummeted. As of September 2024, over 550 000 hectares of cropland have been flooded, and this has added to some 32 million people already facing acute hunger in the country reported in March.^{57,58} Since the economy of Borno state is largely based on agriculture and many households rely on subsistence farming, the destruction of crops by floods and other disasters will continue to leave inhabitants without food or income. This has caused food inflation and an increase in the prices of food, pushing more people into extreme poverty, food insecurity, and hunger even after the recession of the flood.⁵⁹
2. **Malnutrition in Children:** Food insecurity has strong associations with several adverse outcomes that lead to childhood malnutrition including reduced dietary diversity, maternal depression, and stunting.⁶⁰ Children in Borno State who are already disproportionately affected by malnutrition, are now reporting more cases of severe acute malnutrition with medical complications.⁶¹ Without access to adequate food and nutrients, children who have been displaced from their homes also have little to no access to clean water and sanitation and are therefore more susceptible to infectious diseases and developmental delays.⁶² As the floods begin to recede and people return to their homes, the healthcare system and aid agencies must be prepared to treat infections and outbreaks such as cholera which are already being reported,⁶³ otherwise, this may contribute to the vicious malnutrition-infection cycle and further deteriorate the health of the children and survival outcomes.
3. **Access to Humanitarian Aid:** As the government and aid agencies begin to respond with support for displaced communities, there emerges the problem of impeded access to communities. Flooding often cuts off road access to affected areas,^{64,65} making it difficult for humanitarian organizations to deliver food and medical

supplies. There have been reports of damage to key infrastructure such as road networks and bridges in Borno state due to the floods which have isolated communities and disrupted the delivery of aid.^{66,67} This includes Fori, Lagos, and Customs bridges—the 3 main bridges in the city of Maiduguri, the capital of Borno state.⁶⁸ This isolation exacerbates malnutrition and increases mortality, especially among children and the elderly.

The Double Burden of Conflict and Climate Change

Climate change and conflict are 2 of the most pressing challenges facing the global community, and their intersection exacerbates vulnerability in many regions. The effects of climate change, such as rising temperatures, shifting weather patterns, and increased frequency of extreme events, contribute to resource scarcity, which can ignite or intensify conflict.⁶⁹ Conversely, conflict impedes efforts to mitigate and adapt to climate change, creating a vicious cycle that deepens the crisis for communities already at risk.⁷⁰ Understanding the relationship between climate change and conflict is critical to comprehensively addressing both problems. In regions where conflict is prevalent, the effects of climate change are magnified. For example, countries in the Sahel region of Africa, already grappling with political instability and armed conflict, face the added challenge of environmental degradation and unpredictable weather patterns. This combination has led to food insecurity, displacement, and increased resource competition, further destabilizing the region.⁷¹ As climate change reduces agricultural productivity and access to water, tensions rise between different groups, mainly pastoralists, and farmers, over shrinking resources, making conflict more likely.⁷²

Moreover, conflict disrupts the infrastructure and institutions necessary to respond to the impacts of climate change. Governments may struggle to provide essential services in conflict zones, including disaster preparedness and environmental management. The breakdown of governance, coupled with displacement and destruction, hampers the ability to implement adaptation strategies, leaving affected populations even more vulnerable to climate-induced shocks.⁷³ The double burden of conflict and climate change disproportionately affects marginalized groups, who are often left without adequate protection or support. International cooperation and policy interventions must consider environmental and socio-political factors in addressing the dual crises of conflict and climate change. Strengthening governance and promoting sustainable development in conflict-prone areas can reduce the risks of climate-induced conflict while integrating peacebuilding efforts into climate adaptation strategies can help build resilience in vulnerable communities.⁷⁴

Borno State, located in northeastern Nigeria, has long been a region affected by insurgency, especially due to the activities of Boko Haram and other armed groups.⁷⁰ The conflict has resulted in significant loss of life, widespread displacement, and

the destruction of infrastructure, leaving communities in a precarious situation. At the same time, the region is grappling with the impacts of climate change, particularly in the form of frequent and severe flooding. These floods come at a time when Borno State is already grappling with a complex humanitarian crisis driven by years of conflict and displacement.⁷⁵ The combination of conflict and climate change has created a “double burden” that complicates the efforts of the government and humanitarian organizations to address both immediate and long-term health needs.⁷⁶

The frequent flooding in Borno State exacerbates existing vulnerabilities caused by the conflict. Many internally displaced persons (IDPs) live in camps or informal settlements that are poorly equipped to withstand extreme weather events, such as floods.⁷⁷ As a result, these populations are at increased risk of waterborne diseases, such as cholera, and vector-borne diseases, such as malaria, which thrive in flooded conditions. The ongoing conflict further complicates the situation by limiting access to healthcare facilities and disrupting public health programs that are vital to mitigating the spread of these diseases.⁷⁸ Moreover, the conflict has severely weakened the healthcare infrastructure in the state, making it difficult to manage climate-related health emergencies effectively. Public health programs aimed at addressing infectious diseases and malnutrition, which were already under strain due to the conflict, now face additional challenges from climate change-induced flooding. Resources are stretched thin, and the need for clean water, sanitation, and hygiene (WASH) programs is greater than ever. However, the insecurity in many parts of the state hampers the ability of both the government and humanitarian organizations to deliver these essential services.⁷⁹ The effects of this double burden are not limited to infectious diseases. Food security is also a significant concern, as flooding destroys crops and disrupts food distribution networks. This increases malnutrition, especially among children, which remains one of the leading causes of mortality in the region.⁸⁰ The conflict further affect food insecurity, as farmers cannot cultivate their land due to the fear of attacks by insurgents, and humanitarian organizations struggle to access those in need. The intersection of conflict and climate change in Borno State significantly strains health services, aggravating the public health crisis. The situation calls for a coordinated response that addresses both the immediate and long-term challenges, including improving access to healthcare, reinforcing public health programs, and implementing climate adaptation strategies.

Proposed interventions to mitigate flooding

Interventions to mitigate flooding in Borno include construction and expansion of drainage systems to handle heavy rainfall and rising water levels during the raining seasons, tree planting and afforestation to enhance water absorption and reduce surface runoff as well as implementing sustainable land-use practices to prevent soil erosion and excessive runoff.⁸¹ The strengthening of

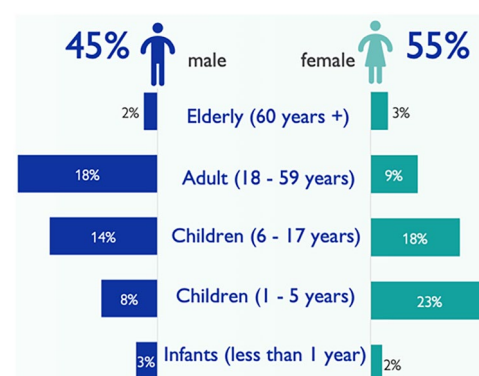


Figure 6. Demographic breakdown of population affected by flood in Borno. Source: Displacement Tracking Matrix (DTM) of the International Organization for Migration (IOM), September 2024.

rivers and dams through regular maintenance, dredging, and clearing of waterways has proven to be significant to preventing blockages.⁸¹ Restriction of construction in flood-prone areas may also reduce risks of flooding. Additionally, increasing public awareness campaigns on flood preparedness and promoting sustainable practices and actions along with highlighting the consequences of unsustainable practices.⁸¹

Demographic analysis of population affected by the flood in Borno. The flooding in Borno particularly the 2024 flood had a significant impact on various demographic groups, further intensifying the challenges faced by already vulnerable populations. In a region already grappling with insecurity and widespread poverty, the flood amplified the hardships of vulnerable populations such as women, children, and internally displaced persons. The disaster not only displaced more people but also exacerbated food insecurity, limited access to healthcare services, and increased health risks.⁸² Adults and elderly were also impacted with 20% male and 12% female displaced without access to food and healthcare as shown in Figure 6. This highlights the need for targeted interventions and relief for the vulnerable populations.

Socio-economic impacts of flooding. The Socioeconomic impact of flooding in Borno state will likely persist for a considerable time. Ninety-three percent of displaced locations in Borno report food insecurity likely due to the destruction of crops, markets, and source of livelihood. Ninety-one percent of these areas had need for shelter as many residents have been displaced from their homes with majority of properties damaged causing long-term housing instability and strain on local resources.⁸³ Flooding has resulted in substantial loss of possession and increase in poverty with many households not being able to meet basic needs. Flooding also caused disruption in education with 84% of the displaced population losing access to educational facilities. Additionally, the flooding had serious health impact with 96% of cases related to acute diarrhea and cholera due to contaminated water and poor sanitation. This increases healthcare costs and reduces productivity as people

fall ill. Collectively, these factors underscore the urgent need for comprehensive recovery and support strategies in the aftermath of flooding in Borno State.

Public health interventions and challenges

The public health challenges posed by climate change-induced flooding in Borno State are multifaceted. Infectious diseases such as cholera, diarrhea, and malaria are rampant in flood-affected areas due to a lack of clean water and sanitation. Additionally, malnutrition is a critical issue, particularly among children. Public health interventions are critically needed but face numerous obstacles. Healthcare systems in the region are already strained due to conflict, with limited resources to manage both endemic diseases and emerging climate-induced health crises. Access to healthcare is significantly restricted, especially in hard-to-reach areas where floodwaters block roads and destroy communication lines.⁸⁴

Moreover, the collapse of health infrastructure has left many without access to medical care, significantly aggravating the spread of infectious diseases such as cholera and malaria. Research has highlighted that the destruction of health facilities and limited access to clean water are key factors that increase the risks of waterborne diseases during floods. Studies have shown a marked increase in cholera outbreaks in flood-affected areas, stressing the urgent need for public health interventions and disease surveillance.⁸⁵ In addition to physical health challenges, there is a psychosocial toll on families, who are now displaced and struggling to survive in makeshift camps. The emotional and mental health impacts of losing homes, livelihoods, and access to essential services like schools and healthcare cannot be overstated. Long-term recovery efforts must include psychosocial support for the affected populations, as well as rehabilitation of infrastructure to prevent future disasters.⁸⁵

Overall interventions

Effective mitigation strategies would also require addressing broader structural issues such as poverty reduction, investment in resilient infrastructure, and stronger health surveillance systems. Collaboration between local and international bodies is crucial to developing comprehensive solutions that integrate both immediate relief and long-term resilience-building in response to flooding and its associated public health risks. Moreover, strengthening disease surveillance is another critical public health intervention. The lack of an efficient system to monitor and respond to disease outbreaks in flood-affected areas has been a major challenge in Borno State. Coordination among local health authorities, humanitarian organizations, and international health agencies is vital for rapid detection and response to infectious disease outbreaks. For instance, without adequate surveillance, the region remains vulnerable to delayed responses to cholera or malaria outbreaks, which can spread quickly in flood-ravaged areas (*HumAngle*). Also,

access to clean water is one of the most pressing issues for the displaced populations living in IDP camps, where sanitary conditions are inadequate. The need for flood-resistant water and sanitation systems cannot be overemphasized. The provision of clean water, combined with improved sanitation, is essential to prevent outbreaks of diseases like cholera, which have ravaged flood-prone regions.

Furthermore, flooding disrupts agricultural practices, causing a direct impact on food availability and leading to malnutrition. Borno State, already struggling with food insecurity due to ongoing conflict, faces additional challenges in ensuring adequate food supply for displaced populations. Programs aimed at providing immediate food aid, particularly to vulnerable populations such as children, pregnant women, and the elderly, must be prioritized. Long-term solutions, such as promoting climate-resilient crops and sustainable agricultural practices, are essential in improving food security and reducing malnutrition rates. Therefore, the repeated destruction of healthcare infrastructure by floods presents a significant challenge to addressing public health crises in Borno State. Health facilities need to be rebuilt or fortified to withstand the dual pressures of increased disease burden and malnutrition following flood events. Furthermore, training healthcare workers in disaster management and ensuring they have the resources to handle the unique challenges posed by climate-induced health emergencies is crucial for improving healthcare delivery as shown in Table 1 below:

In addition, building climate resilience within communities is critical in minimizing the long-term impacts of flooding. Educating local populations on the risks associated with floods and equipping them with knowledge on how to protect their health during such events can reduce the severity of disease outbreaks. Additionally, integrating climate-resilient practices into local agricultural and economic systems can mitigate food insecurity and prevent malnutrition during future floods. Resilience-building strategies, including flood preparedness and sustainable land-use planning, must be incorporated into local development plans.

Conclusion

Climate change-induced flooding in Borno State, Nigeria, has exacerbated the prevalence of water-related diseases and malnutrition, posing a severe public health crisis. The impacts are multifaceted, ranging from outbreaks of cholera and typhoid to increased rates of child malnutrition, all of which undermine the well-being of already vulnerable populations. Addressing this crisis demands a holistic approach: strengthening healthcare systems, improving water and sanitation infrastructure, and scaling up nutrition programs are crucial steps. Equally important are proactive disaster preparedness measures, including the establishment of early warning systems and climate-resilient infrastructure, as well as robust policy frameworks to enforce climate adaptation strategies. Community education and active participation are indispensable for sustaining interventions and

Table 1. Recommendations to mitigate the impact of climate change-induced flooding on water-related diseases and malnutrition in Borno State, Nigeria.

RECOMMENDATION AREA	KEY ACTIONS	STAKEHOLDERS INVOLVED	EXPECTED OUTCOMES	RELEVANT SDG
Strengthening health systems	Establish emergency health response units for flood-affected areas. Provide mobile clinics to reach displaced and remote populations.	Ministry of Health, NGOs, WHO Local governments, international donors	Rapid response to disease outbreaks, reduced mortality rates Increased access to medical care for vulnerable groups	SDG 3 (Good Health and Well-being)
Improving water and sanitation	Construct flood-resilient water and sanitation infrastructure. Implement community-led total sanitation (CLTS) programs.	Federal Ministry of Water Resources, UNICEF Community leaders, NGOs	Reduced waterborne diseases like cholera and typhoid Enhanced hygiene practices and reduction in open defecation	SDG 6 (Clean Water and Sanitation)
Addressing malnutrition	Scale up nutrition interventions, including provision of fortified foods Establish community gardens for sustainable food supply.	Local NGOs, community organizations Local NGOs, community organizations	Reduced reliance on external food aid, increased food security Reduced reliance on external food aid, increased food security	SDG 2 (Zero Hunger)
Disaster preparedness	Develop early warning systems for floods and other climate-related events. Train community members on disaster risk reduction strategies.	Nigerian Meteorological Agency (NiMet) Red Cross, NEMA, local governments	Better preparedness and reduced impact of flooding events Empowered communities with resilience to climate-induced crises	SDG 13 (Climate Action)
Education and advocacy	Launch public awareness campaigns on flood-related health risks. Integrate climate change and health education into school curricula.	Media, local leaders, NGOs Education boards, schools	Increased community knowledge and proactive participation in solutions Future generations equipped with knowledge to address climate challenges	SDG 4 (Quality Education)

building resilience against future climate-related challenges. By fostering multi-stakeholder collaboration and aligning interventions with the Sustainable Development Goals (SDGs), Borno State can mitigate the devastating impacts of flooding, safeguard public health, and pave the way for a sustainable and resilient future. The urgency of action cannot be overstated climate adaptation is not just a choice but a necessity for protecting lives and livelihoods.

Author Contributions

A.T.A, A.O.A, and O.J.O. conceptualized the current study. A.T.A wrote the first draft manuscript. A.T.A., O.J.O., A.O.A., O.S.O., G.A.A., N.J.A., I.O.O., A.A., G.Y.S., B.O.K., and J.J.K. edited and reviewed the manuscript. All authors have read and agreed to the published version of the manuscript.

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