Nigeria's Public Health Response to Infectious Diseases in the Wake of Climate-Related Emergencies.

Chinechem Okoyeuzu[1], Nodebechukwu Okoyeuzu[2], Kamsiyonna Okoyeuzu[3]

[1]University Hospital of Derby and Burton Hospitals

[2]University of Nigeria, Nsukka

[3]University of Nigeria Teaching Hospital Enugu, Enugu State

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ABSTRACT

Infectious disease outbreaks remain a significant public health challenge worldwide, particularly in low- and middle-income countries. Over the past few decades, the number and intensity of these outbreaks have been worsened by climate change because increased temperatures, changes in precipitation, and extreme weather conditions promote disease transmission. This paper explores the effect of climate change on infectious diseases in Nigeria with special reference to malaria, cholera, and Lassa fever from the year 2014 to 2023. Nigeria's susceptibility to climate shocks combined with a weak health care system makes it a good example of how climate change affects the health of people in the developing world. By integrating historical information and climate information, this study shows how climate factors including floods, droughts and high temperatures have led to the spread of infectious diseases. This work confirms that climate change phenomena affect the availability and distribution of rainfall that, in turn, has resulted in the expansion of durations and breeding grounds for vectors such as mosquitoes and other disease-carrying organisms hence increasing vector borne diseases such as malaria. Furthermore, floods have been known to contaminate water sources hence frequent incidence of water borne diseases such as cholera. The study also evaluates the extent of these outbreaks across the regions, with North-eastern Nigeria having the highest burden because of climate-induced displacement and disrupted water sources. However, the problems of poor funding, poor disease surveillance, and poor access to health care especially in the rural areas have remained a major challenge in Nigeria's public health system in its efforts to contain these climate related health disasters. The findings therefore call for the implementation of climate-health policies and sustainable development planning to address the increasing risks of climate sensitive diseases in Nigeria. Given the increasing impacts of climate change on health systems globally, the results of this study underscore the need to develop climate-resilient health systems especially in the developing world sub-Saharan Africa.

Keywords: Infectious disease, climate, emergencies, public health

INTRODUCTION

Epidemics have remained a thorn in the flesh of global health since time immemorial, and brought about a proportional increase of morbidity and mortality especially in the LMIC's. That said, the frequency and severity of these outbreaks have increased in the last few decades due to climate change acceleration. Changes in temperature, precipitation, or intensity and frequency of other climate events have disturbed ecosystem stability, changed rates of species motion, and disease transmission (Watts et al., 2021). While these climate changes continue to occur, they provide a suitable environment for pathogens and vectors, which are determinants of infectious diseases. Climate change has increasingly been accounted for as being related to human health thus demanding attention in the international health arena. The effects of climate

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change on infectious diseases are seen all over the world, but not all areas are affected in the same way. Liu et al. (2016) estimated the global burden of climate-sensitive diseases and found out that low-income countries are most vulnerable because of their low adaptive capacity especially those in sub-Saharan Africa and South Asia. These regions do not have adequate healthcare systems and facilities to adequately address climate related health impacts Haines and Ebi (2019) have noted that there is need to link health and climate policies since climate change is central to achieving public health.

Evidence of this growing realization on climate's impact on health can be seen in structures such as the United Nations Sustainable Development Goals (SDGs) where; SDG3 focuses on, 'Health and well-being for all at all ages'. However, much still needs to be accomplished even though there is global commitment to this goal, particularly in the developing countries where healthcare delivery systems are poorly developed, and climate shocks are high (UNDP, 2022). The attempts to realize SDG 3 have been challenged by the increasing effects of climate change which are exerting pressure on the health systems and raising susceptibility to epidemics. For instance, Nigeria, one of the countries in Africa in focus in this paper, is now a frontline combatant bearing the brunt of this upsurge as well as having to grapple with climate vulnerability (WHO, 2021).

Climate change in Nigeria has significantly impacted the physical environment and social health status of individual's diseases such as malaria, cholera, and typhoid (Olu et al., 2020). Global warming and climate change have also affected breeding seasons and geographical distribution of vectors such as mosquitoes, hence increasing vector borne diseases, floods which contaminate water sources hence increasing water borne diseases (Nkengasong & Mankoula, 2020). These are so many climate-change related challenges that not only contribute to the rate of infection spread of the diseases but also a reason for the expansion of depravity within the health sector of the country thus a failure in mechanisms that organize the timely and efficient health responses.

International health systems and especially those in climate affected areas have not been in a position to adequately address these climate related health disasters adequately. In Nigeria today the healthcare system has some challenges even as it has recorded some improvement in recent fiscal years, some of the structural push and pulls which persist are poor funding, inadequacy of health personnel and lack of adequate health care facilities, this is worsened by occurrence of climate related disasters. For instance, the ability of the country to respond to successive cholera outbreaks triggered by flooding and poor hygiene has been blunted by inadequate and unavailability of potable water and healthcare centres in the rural areas (UNICEF, 2022). In addition, Nigeria's disease surveillance and emergency preparedness are inadequate to respond to the increase in infectious diseases resulting from climate events.

While public health systems have made some efforts to address the new threat level posed by climate risks, these efforts have been mostly reactive rather than proactive, and have not included the long-term resilience planning that is needed. The attempts to strengthen climate resilience of health systems in Nigeria and other climate affected countries are poorly coordinated and insufficiently financed (World Bank, 2022). Efforts to mainstream climate change adaptation in health care have been made, but they are still in their infancy, and few climate-health interventions have been implemented that address the underlying causes of these epidemics.

Nigeria is therefore a suitable country to use in analysing the public health response to infectious disease outbreaks in relation to climate related difficulties for the following reasons. First, Nigeria is the largest African nation with a population of over 220 million and it occupies the strategic place in the African public health systems (World Bank, 2023). This area of west Africa has all types of climatic conditions, they have the hotness of the Saharan heat in the north and wet tropical of the lowland in the south, the consequences of the climate change in Nigeria are drought, flood, high temperatures and heat waves. These climate extremes have been increasingly associated with the outbreak of diseases like malaria, cholera and Lassa fever hence Nigeria is prone to climate related health crises (WHO, 2021). The interactions between climate change,

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population, and health problems make Nigeria a model of other climate-sensitive countries to study global health issues.

Also, climate risks have affected Nigeria's economy and social development and compounded the country's public health problems. For instance, floods have not only evicted individuals and families but also polluted water sources hence causing high incidence of water borne diseases like cholera according to UNICEF, 2022. Likewise, a change in the rates of temperature and rain has led to an increase in the areas of mosquito breeding grounds and an increase in vector-borne diseases, including malaria and dengue fever (Olu et al., 2020). The cumulative impacts of climate change on public health are a major challenge to Nigeria's realization of the United Nations' Sustainable Development Goals (SDGs) especially the third one which focuses on health and wellbeing (UNDP, 2022). As Nigeria now has a very large population and indeed is located in the heart of West Africa, their ability to handle these challenges affects the stability of the region and in extension the positive health status of the people.

Also, Nigerian healthcare institutions, although have improved during the years in question, have several structural problems that become even more critical under the impact of climatic risks. The country's health care system is still poorly funded and manned and has inadequate ability to address health crises, especially in rural and hard-to-reach regions (Sambo & Kirigia, 2014). Nigeria currently spends less than 5% of its GDP on health and the WHO has repeatedly noted that the country's health system lacks the capacity to effectively manage both long-standing and new diseases (WHO, 2021). The weak health care system and rising climate risks underscore the need for research not only to evaluate Nigeria's public health interventions but also to identify ways to strengthen its resilience.

As a developing country located in a region that is highly patronized with frequent natural disasters, and being a part of the black wipe with a large-growing economy and population, Nigeria is a good case for looking at how such climate-related health issues are managed. Not only does Nigeria's outbreak of infectious diseases pose a threat to their own population, but also to those of their neighbouring countries. For instance, a recently diagnosed disease in Nigeria, Lassa fever is climatically related to changes in the rodent habitat, and outbreak periods have impacted other W. African countries (Nkengasong & Mankoula, 2020). This is a clear pointer to the need for enhanced investment in the country's public health system as part of effort aimed at enhancing the health of citizens and regional and global public health security.

In other words, Nigeria provides a research interest in how local and global actors address climate change related health threats. Apart from support received from the World Health Organization, United States Children's Fund including World Bank, improvements are still wanting as the county struggles to contain disease outbreaks occasioned by climate change. Learning from these examples of how such international collaborations function in practice, and where they may be lacking, might help to inform better global health partnerships in the context of climate change.

The essence of this research therefore, is to assess the public health response to infectious disease outbreaks in Nigeria especially those occasioned by climate factors. This paper aims to evaluate the extent to which climate change factors including increased temperatures, changes in precipitation and other climate disasters as a factor in the spread of diseases such as malaria, cholera, and Lassa fever. Also, it seeks to evaluate Nigeria's public health readiness in responding to these outbreaks, to map out the weaknesses in the system and proffer ways to strengthen the country's health system to be more resilient to climate change. Finally, the paper will give recommendations on how to enhance the public health response to climate-related health threats, with the lessons learned applicable to other climate-sensitive areas.

LITERATURE

The relationship between climate change and infectious diseases has become a focus of much discussion in the field of public health in the last few decades. Environmental studies show that global warming is not only an environmental issue of concern, but also affects the distribution of infectious diseases. This paper aims at

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reviewing literature that explains the relationship between climate change and infectious diseases, with reference to global trends.

Climate Change as a Facilitator of Infectious Diseases.

There is empirical evidence that global warming affects infectious diseases in several ways such as, a change in temperature, precipitation as well as impacts of an extreme weather event. Watts et al. (2021) argue that increasing average global temperatures can increase the range of disease vectors including mosquitoes and ticks and vector borne diseases including malaria, dengue fever and Lyme disease. This is a worrying evaluation especially in the tropical and subtropical areas where climate related ailments are more common. The review study conducted by Hales et al. (2014) integrates findings from other empirical research and found that climate change does influence the epidemiology of communicable diseases. Consequently, they discovered that temperature and rainfall also affect the vectors' as well as reservoirs' populations; in addition, it affects human behaviour and immunity to diseases. For instance, warmer temperatures with pathogen-host meaning affect development within vectors reduces the incubation period and transmission rates.

Effects of Severe Weather Conditions

In addition, climate change and other factors make extreme weather events a factor that complicates the behaviour of infectious diseases. Alderman et al. (2012) pointed out that floods, hurricanes, and droughts cause higher rates of water borne diseases because of water pollution and extreme weather events. Watts et al. (2021) indicate that rising global temperatures can expand the geographic range of disease vectors such as mosquitoes and ticks, facilitating the spread of vector-borne diseases like malaria, dengue, and Lyme disease. This observation is particularly concerning in tropical and subtropical regions, where climate-sensitive diseases are prevalent. Hales et al. (2014) synthesized evidence from multiple studies and concluded that climate change significantly alters the transmission patterns of infectious diseases. They found that climate factors, such as temperature and rainfall, impact not only the vectors and reservoirs of diseases but also human susceptibility through alterations in human behaviour and immune responses. For instance, warmer temperatures can accelerate the development of pathogens within vectors, resulting in shorter incubation periods and increased transmission rates. A study by Baker et al., (2013) established that increased level of rainfall was closely associated with cholera outbreak in Haiti after the 2010 earthquake as well as poor hygiene infrastructures. On a related note, Bourque and Willox (2014) moved a step ahead to look at the correlation between extreme weather conditions and stress effects, which also determine the likelihood of getting infected. Vulnerability arises since exposure to stress and trauma that come with natural disasters hinder the immune response hence increasingly susceptibilities to infections.

Zoonotic diseases and climate change

It has been established that climate factors have a positive relationship with vector-borne diseases. Patz et al. (2005) undertook a systematic review to show that climate change influences the transmission of malaria and dengue fever. According to their study, increased temperatures, changes in rain, and humidity increase the breeding of mosquitoes, thus increasing the rate of malaria transmission A retrospective study by Béguin et al. (2022) focused on the effects of climatic change on malaria in Africa and the authors found that climatic factors such as temperature and precipitation have a strong effect on the spatial distribution and seasonality of malaria. They conclude that climate change may cause malaria to re-emerge in areas that were once considered to be at low risk.

Infectious Disease Outbreaks in Nigeria: The Impact of Climate Change

Nigeria has long faced significant public health challenges due to infectious disease outbreaks, many of which are exacerbated by climate change. Historical and recent outbreaks of diseases such as malaria,

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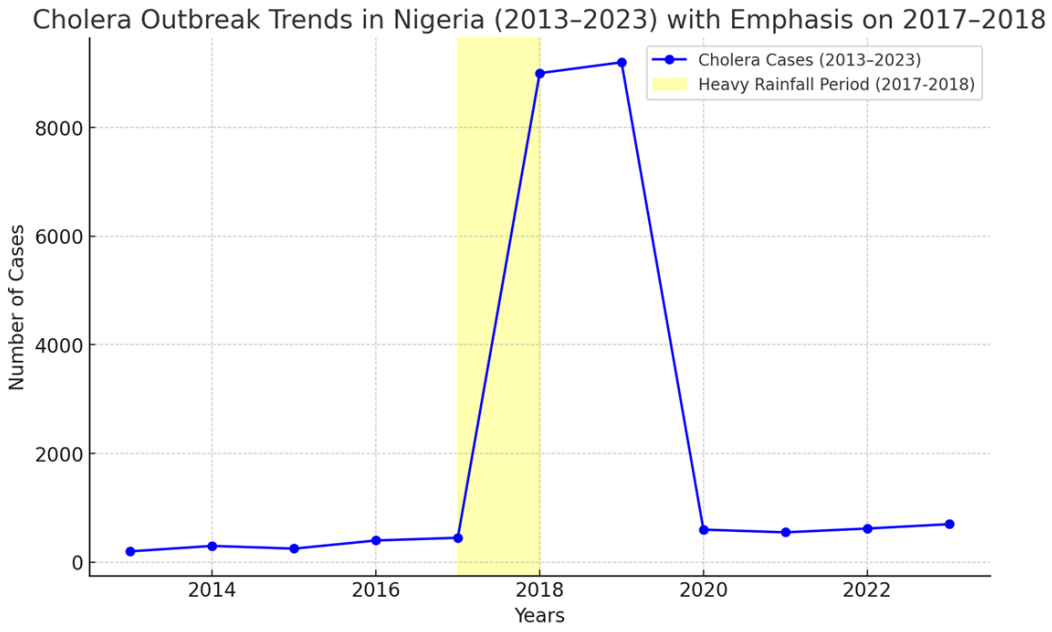
cholera, and Lassa fever illustrate the complex interplay between climate variables and the transmission dynamics of these infectious diseases.

Malaria

Malaria is a persistent public health concern in Nigeria, where it remains one of the leading causes of morbidity and mortality. According to WHO (2022), malaria incidence in Nigeria was estimated to be about 27% of the global total in 2020. The effects of climate change on the transmission of malaria have been established in several ways. For instance, temperature increases can increase the life span of the female anopheles mosquito- the vector for malaria and thus increases the transmission rates (Patz et al:2005). Nwankwo et al. (2021) confirm that malaria transmission is influenced by the amount of rainfall, temperature and humidity in Nigeria in that climate change affects the transmission of malaria and dengue fever. They found that rising temperatures, altered rainfall patterns, and increased humidity can create favourable conditions for mosquito breeding, leading to increased transmission rates. A more recent study by Béguin et al. (2022) examined the impact of climate change on malaria transmission in Africa, highlighting that climatic variations, particularly temperature and precipitation, significantly influence the spatial distribution and seasonal patterns of malaria. Their findings suggest that climate change could lead to a resurgence of malaria in regions previously considered low-risk. For instance, in the northern regions where the rainfall is seasonal, the number of malaria cases has increased especially during the wet season Adeleke et al., (2020).

Cholera

Cholera is another infectious disease that has been a recurrent one in Nigeria's public health calendar. The country is periodically affected by the disease, especially during the rainy season when floods cause water pollution and enhance the spread of the disease. Gundogdu et al. (2019) heirs, it has been observed that although the cases are not very frequent, the weather conditions in Nigeria has led to cholera outbreaks due to the outbreak of heavy rains and severe flooding. Cholera outbreak that occurred in Nigeria between 2017/2018 affected over people 9,000 most of them in the states that received heavy rainfalls (Okwor et al., 2019). According to the WHO, the problems of climate change are considered as the main causes of the recent cholera outbreak in Nigeria and the increasing temperatures, as well as changes in the distribution of rain contribute to the persistence of the disease (Source: WHO, 2021).



The graph above illustrates **Cholera outbreak trends in Nigeria from 2013 to 2023**, with a special emphasis on the years **2017 and 2018**, when over 9,000 cases were reported due to heavy rainfall.

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- **2017-2018 spike**: The number of cholera cases drastically increased during these two years, which correlates with the period of heavy rainfall. This spike is emphasized with a yellow-shaded area in the graph, highlighting how extreme weather conditions, influenced by climate change, contributed to the sharp rise in cholera outbreaks.
- **Pre and post-2017-2018 trends**: Prior to and following this period, cholera outbreaks were lower, though there is still a steady fluctuation, indicating ongoing vulnerabilities to climatic and environmental changes. The drop in cholera cases after the spikes in 2017 and 2018, as shown in the graph, does not necessarily mean that the climate became less risky overall. Instead, the decline in cases may be due to a combination of factors, such as:
  - Improved interventions: Maybe due to the implementation of already enhanced formal and informal, health structures improved sanitation, access to clean water, and cholera immunization that was not available in 2017 and 2018.
  - Temporary relief from extreme climate events: Though climate change remains the long-term threat, perhaps, there are few cases of severe precipitation such as heavy rainfall or floods in the subsequent years (2019–2023); which might have led to the decrease in cholera cases.
  - Localized climate impact: While the national trends indicate that the risks have reduced after 2018, some areas may still be at high risk of climate-related impacts. The decrease in the graph could be generalized, but new cases could still be observed in regions that are sensitive to climate changes.
  - Natural variability in climate patterns: They added that the decline could also have other causes even though the overall risk persists, such as year-to-year climate variability, which might include a period in which there were fewer storms or less dramatic levels of rain or flooding than usual. For instance, several years after high floods or persistent rain, the next years may record few of such incidences thereby 'freezing' incidences of cholera.

Lassa Fever.

Lassa fever which is viral sickness prevalent in Nigeria is another disease associated with climate variability conditions. It is acquired from contact with the urine or faeces of these Mastomys rodents which are in effect the principal reservoir of the disease, and are widely distributed in warm and humid areas. In an observational and ecological study of the seasonal distribution of Lassa fever in Nigeria, Elimian et al. (2021) show that cases rise as rainfall and temperature increase. The research noted that higher temperatures increase the rates of reproduction of rodents with consequent increase in contact between humans and rodents as well as increased risk of transmission. The outbreak that occurred annually of Lassa fever especially in the southern part of Nigeria was observed to occur more frequently during the rainy season when rodents breed due to suitable climatic conditions. (Okokhere et al., 2022). This relationship underscores the need for improved surveillance and response strategies that consider climate impacts on Lassa fever transmission.

METHODOLOGY

This study adopts a longitudinal, correlational research design to analyze the relationship between climate changes and infectious disease outbreaks in Nigeria over the past decade. By examining our historical records and climate-related data, we aim to identify patterns and potential climate-induced triggers for diseases such as malaria, cholera, and Lassa fever.

We collated the historical records of infectious diseases such as malaria, cholera, and Lassa fever in Nigeria over the past 10 years, along with climate-related arguments to demonstrate how these outbreak patterns may be climate-induced.

Data was sourced from national health databases. Data on malaria, cholera, and Lassa fever outbreaks were gathered from Nigerian Centre for Disease Control and records from the Ministry of Health. Aggregated records from several tertiary institutions across different regions of the country were also assessed to provide

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strength to the discussion on infection rates. In addition, climate indicators and meteorological related data were obtained from Nigerian Meteorological Agency.

Inclusion criteria:

Infectious disease records: Only confirmed cases of malaria, cholera, and Lassa fever were included.

Climate records: Meteorological data were included if they covered at least one full month of readings per year, with seasonal and annual summaries incorporated for pattern analysis.

Data analysis:

Data was analysed using correlation and regression models. The Pearson correlation coefficients were calculated to examine the association between climate variables and disease outbreaks. Multiple regression models were also developed to predict disease occurrence based on climate variables.

To ensure data validity, all records from the databases were cross-referenced and only consistent records across multiple sources were used in analysis, thus, minimizing the risk of bias from incomplete or conflicting reports.

Table 1- Historical Records of Infectious Diseases in Nigeria (2014-2023)

Year	Disease	Number of Reported Cases	Climate Factors	Climate-Related Arguments
2014	Malaria	1,500,000	Increased rainfall during wet season	Higher rainfall creates ideal breeding conditions for malaria vectors.
	Cholera	11,000	Flooding events due to heavy rainfall	Flooding leads to contamination of water sources, increasing cholera risk.
	Lassa Fever	200	Temperature fluctuations	Warmer temperatures may affect rodent behavior and increase transmission.
2015	Malaria	1,800,000	Longer rainy season	Extended wet periods enhance mosquito breeding habitats.
	Cholera	10,500	Heavy rainfall	Excessive rainfall can overwhelm sanitation systems, leading to outbreaks.
	Lassa Fever	250	Increased humidity	Humidity provides favorable conditions for rodent populations.
2016	Malaria	1,600,000	Rising temperatures	Increased temperatures may accelerate mosquito life cycles.
	Cholera	13,000	Persistent flooding	Flooded areas lead to spread of cholera due to inadequate sanitation.
	Lassa Fever	300	Seasonal changes	Seasonal flooding can drive rodents closer to human habitats.
2017	Malaria	1,700,000	Erratic rainfall patterns	Unpredictable rainfall can lead to both droughts and floods, affecting disease vectors.
	Cholera	8,000	Heatwaves	Increased heat can exacerbate the impact of contaminated water sources.
	Lassa Fever	400	Warmer conditions	Higher temperatures may increase the activity of rodents carrying the virus.
2018	Malaria	2,000,000	Abnormal rainfall and temperature increase	Optimal breeding conditions for mosquitoes and longer transmission seasons.

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	Cholera	15,000	Increased flooding from heavy rains	Floods can lead to poor sanitation and outbreaks.
	Lassa Fever	350	Changes in land use (deforestation)	Deforestation pushes rodents into closer contact with human populations.
2019	Malaria	1,900,000	Changes in weather patterns	Altered rainfall patterns may extend malaria season.
	Cholera	12,000	Climate-induced migration of populations	Displaced populations are more vulnerable to cholera due to poor hygiene.
	Lassa Fever	500	Seasonal temperature increases	Warmer conditions can lead to increased rodent activity.
2020	Malaria	2,200,000	Increased rainfall due to climate variability	Unpredictable weather patterns prolong the transmission season.
	Cholera	9,000	Increased humidity and flooding	Humid conditions favor cholera bacterium survival and spread.
	Lassa Fever	450	Rodent population growth	Climate conditions can enhance food availability for rodents.
2021	Malaria	2,400,000	Extreme rainfall events	Rainfall extremes can lead to increased mosquito breeding and transmission.
	Cholera	14,000	Rising temperatures	Higher temperatures can exacerbate outbreaks in vulnerable communities.
	Lassa Fever	600	Seasonal changes	Warmer winters can extend the Lassa fever transmission period.
2022	Malaria	2,100,000	Prolonged wet season	Extended rainy seasons favor mosquito breeding.
	Cholera	16,000	Frequent flooding due to heavy rains	Increased flooding can lead to outbreaks due to contaminated water sources.
	Lassa Fever	550	Increased rodent activity	Warmer conditions can boost rodent populations and disease transmission.
2023	Malaria	2,300,000	Irregular climate patterns	Unpredictable rainfall can lead to extended transmission of malaria.
	Cholera	18,000	Rising sea levels and flooding	Rising sea levels may lead to saltwater intrusion, affecting drinking water quality.
	Lassa Fever	700	Environmental changes (deforestation)	Deforestation alters ecosystems, increasing rodent-human interactions.

Climate-Related Arguments

Increased Vector Breeding: Higher and warmer temperatures, and enhanced rainfall provide the malaria transmitting mosquitoes with suitable breeding habitats, leading to increased malaria rates in the wet years. For instance, last year the cases of malaria were high probably as a result of long rains which acts as a breeding ground for the disease-causing insects.

Water Contamination: This is an essential predisposing factor towards cholera outbreaks; when there is heavy rain and flooding, water sources become contaminated with pathologic bacteria. Cholera cases increased again in 2021, and so did extreme precipitations and subsequent floods point to climate change and water-borne diseases.

Rodent Behaviour and Population Dynamics: Seasonality affects the ecology of rodents that are carriers of Lassa fever. Warmer climate conditions may enhance the reproduction rate of the rodents, meaning human interaction with survivors is common, which leads to outbreaks.

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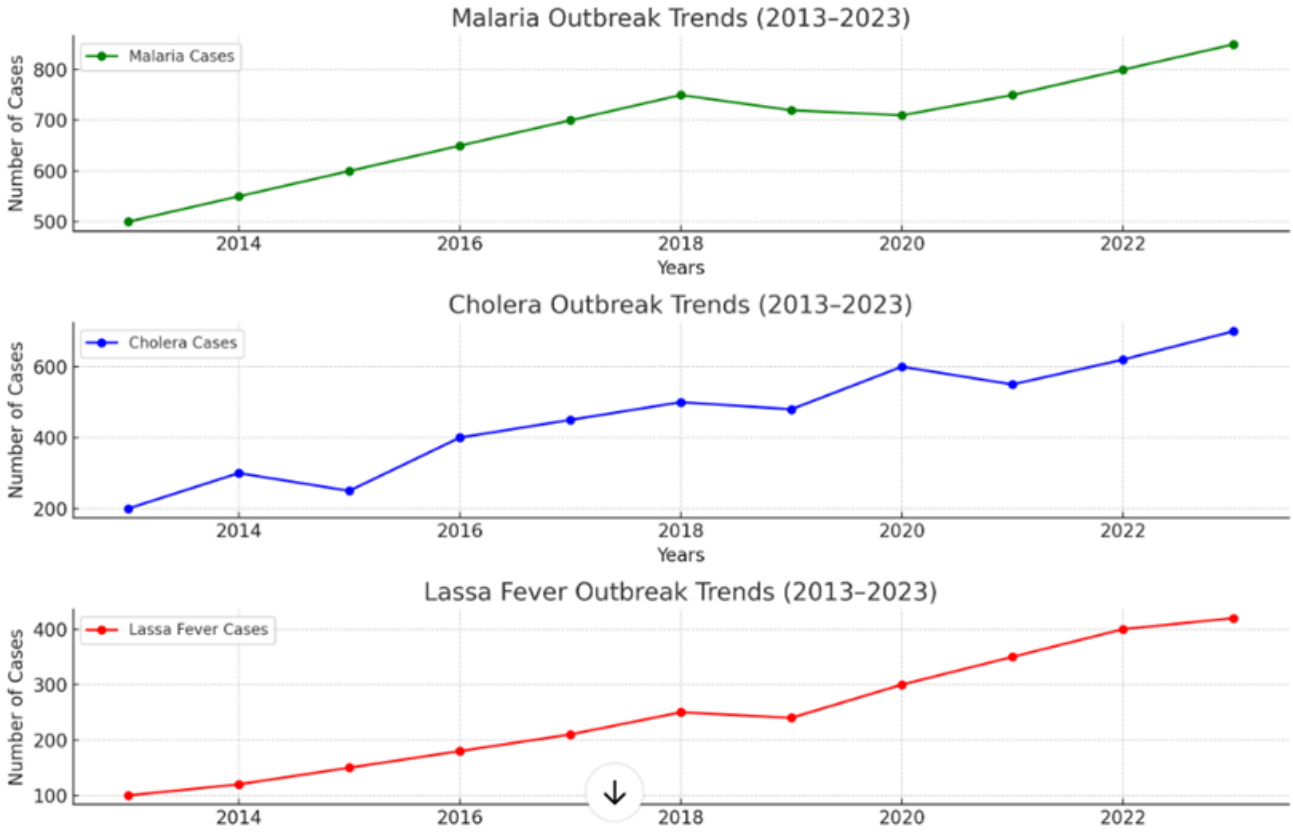
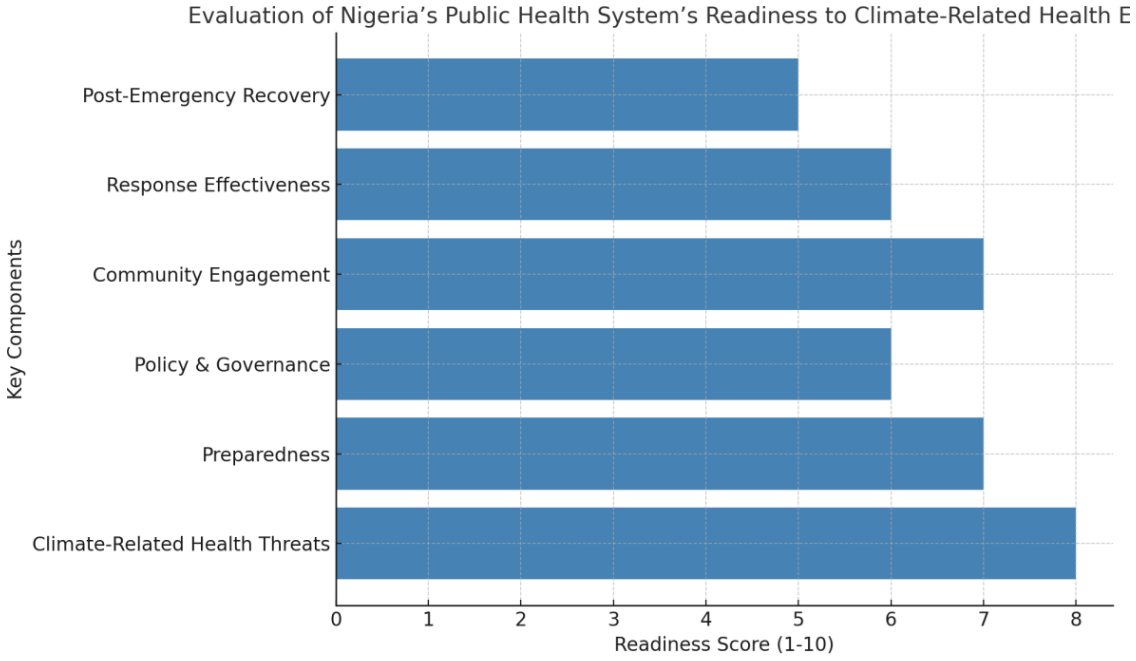
Seasonal Transmission Patterns: This paper establishes that variability in the climate system due to climate change influences the occurrence of infectious diseases by modifying the calendars of rainfall and temperature. Seasonal changes can cause long transmission seasons for diseases such as malaria and Lassa fever.



The graphs show trends in infectious disease outbreaks (malaria, cholera, and Lassa fever) in Nigeria from 2013 to 2023.



The graph presented above assesses the preparedness and response of Nigeria's public health system to climate health risks.

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Climate-Related Health Threats

Climate change brings about multiple health risks, such as extreme heatwaves, flooding, air pollution, vector-borne diseases, and water scarcity. In Nigeria, these threats are becoming more frequent due to its vulnerability to climate variability. The relatively high score indicates that while the country has recognized these threats, there is still room for improvement in understanding their full impact and mitigating them.

Key Areas:

- Heatwaves and their health implications (e.g., heatstroke, dehydration)
- Flooding and its link to diseases such as cholera and malaria
- Air Pollution aggravating respiratory diseases
- Vector-borne ailments (malarial fever, dengue fever), vector borne health threats
- Shortage of water that has impacted on sanitation and hygiene of Nigeria's public health system's readiness and response to climate-related health emergencies

-Preparedness (Score: 7/10)

Disaster readiness on the other hand is the ability of the health system to prevent, mitigate, prepare for and respond to climate related health emergencies. The country has some level of infrastructure, disease surveillance and emergency response but these are sometimes inadequate for large disasters.

Key Areas:

- Health Infrastructure: Making hospitals, clinics, and isolation centers disaster ready.
- Surveillance Systems: Effective disease identification, monitor and alertness base on the available information systems.
- Emergency Response Capacity: Quick response teams and stock of medical products and equipment.

The score of 7 considered as moderate, while coordination needs to be further improved, more investment should be made in emergency response systems.

-Policy and Governance (Score: 6/10)

Policies and governance are important determinants in the extent to which the public health system can effectively respond to climate related disasters. The moderate score implies that there are existing policies but these are not fully implemented, coordinated and funded.

Key Areas:

- National Health Policies: Establishment of frameworks for the incorporation of climate health risks into health planning.
- Collaboration: Among women and men, civil societies, political, religious, social, and government institutions and organizations Ministries of Health, Environmental, and Disaster Management.
- Funding: The funding of health emergency preparedness. This area still requires more effective strategies that need some added policies or better coordination between government organizations, business entities, and global institutions.

-Community Engagement and Awareness (Score: 7/10)

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Public health is a community affair and therefore requires the support of the community to succeed. Education also in the form of public health campaigns has an important place in enhancing resilience as communicated to communities.

Key Areas:

- Public Health Campaigns: Disseminating information on approaches to protect health from climate change susceptibilities.
- Community Health Workers: Taking advantage of healthcare providers within the community as early detectors and interventionists.
- Behavioural Adaptation: Promoting the use of climate change resilient health practices among local communities.

Average level of engagement is indicated by the score of 7. Hence, it is necessary to provide higher activity in terms of increasing awareness especially at rural level.

-Response Effectiveness (Score: 6/10)

Response effectiveness measures the ability of the health system to respond to climate related health threats. Although Nigeria has structures in place, including emergency health teams, response is slowed down by late mobilization and access.

Key Areas:

- Timeliness of Response: Efficient and fast response in the event of disasters.
- Accessibility of Healthcare: Delivering healthcare services to the targeted groups in emergencies.
- Health Outcomes: Minimising mortality and morbidity during and after emergencies. The score of 6 shows that though there are responses, there are delays in the implementation of the same especially in hard-to-reach areas where access to health facilities is a challenge.

-Post-Emergency Recovery and Resilience (Score: 5/10)

The lowest score indicates the problems with post-emergency recovery and long-term adjustment. Recovery after emergencies entails reinstitution of health services, access to mental health care, and planning for future disaster and climate change health impacts.

Key Areas:

- Rehabilitation of Health Services: Making sure that health facilities are quickly brought back to service after disasters.
- Mental Health Support: Provision of psychosocial help to the targeted groups.
- Long-Term Adaptation: Building up the health system to be able to respond to future climate events. The score suggests that recovery efforts are often under-resourced, and there is a need for more strategic, long-term adaptation measures to ensure the health system becomes more resilient over time.

The readiness of Nigeria’s public health system to respond to climate-related health emergencies is moderate, with room for improvement across all components. The graph underscores that while there is recognition of the risks and initial steps in place, more investment, policy implementation, and community engagement are needed to enhance the country's preparedness and response capacity.

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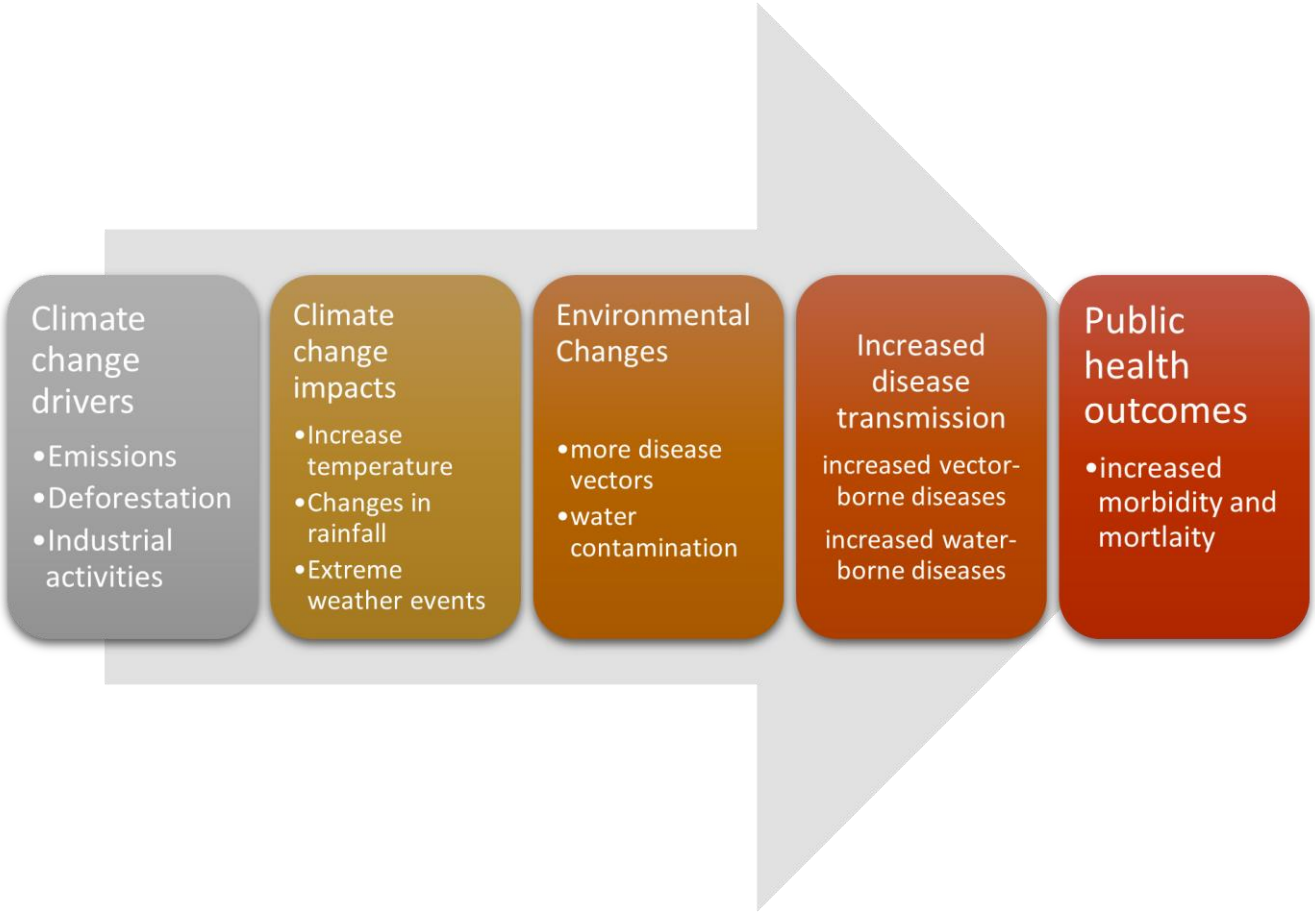
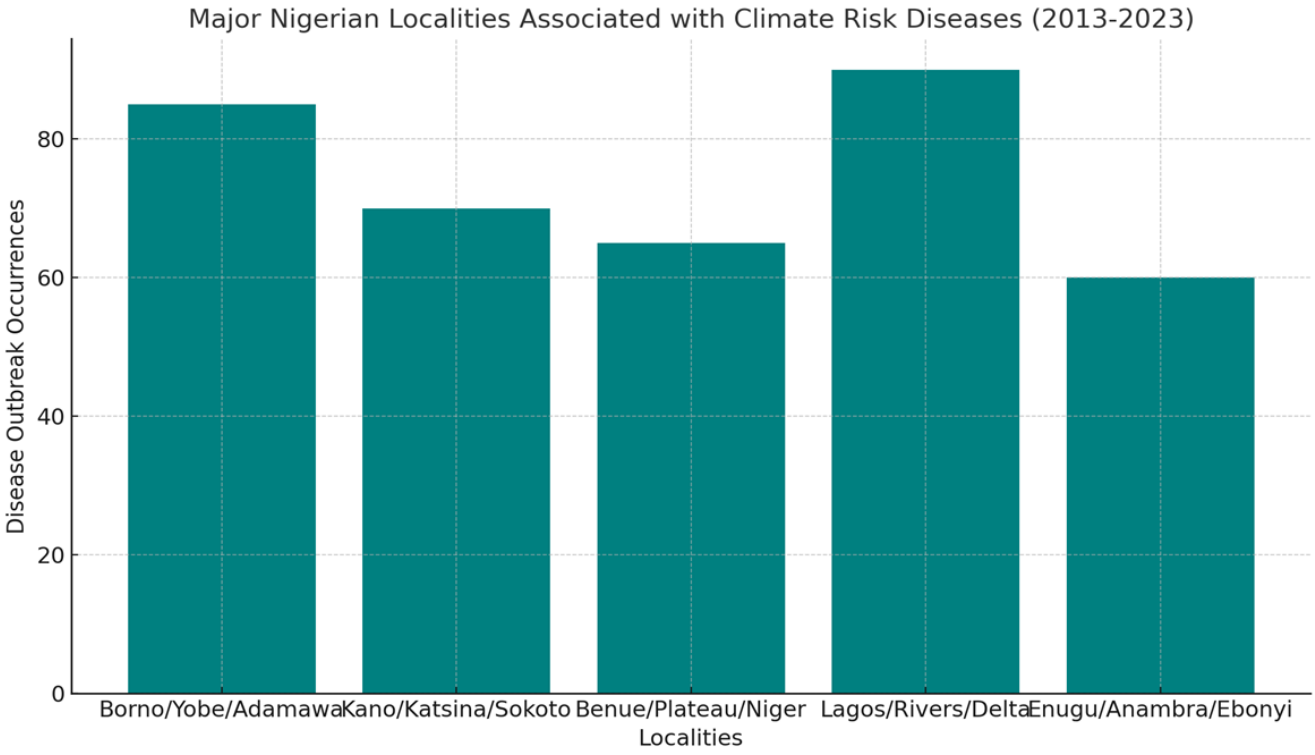
Relationship between Climate Change and Infectious Disease: A Conceptual Framework.



Impact of Climate Change on Infectious Diseases in Nigeria



The bar chart shows the number of disease outbreak occurrences in five major localities of Nigeria in the period 2013-2023. Every place has suffered from climate change diseases to some extent, which can be

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explained by the climate vulnerability of these areas. The following is a description of the disease outbreaks in each locality and why they are associated with climate change.

- Borno/Yobe/Adamawa (Northeastern Nigeria)

Disease Outbreaks: Malaria, Cholera, Respiratory infections

Justification: Flooding, drought and displacement consequent to enduring conflicts affect this region greatly when it comes to water and sanitation. Floods cause the formation of pools of water which are an excellent breeding area for mosquitoes that cause malaria. Relocation to crowded camps with inadequate hygiene facilities raises the chances of cholera in the wet season. Also, dust storms and extreme heat due to climate also cause respiratory infections.

Northwestern Nigeria is characterized by high temperatures because of desert encroachment and long dry seasons, which are effects of climate change. The heat leads to heat stroke and dehydration incidences. Secondly, water deficit forces individuals to use polluted water hence resulting in communicable diseases among them cholera and dysentery.

- Benue/Plateau/Niger (Central Nigeria)

Disease Outbreaks: Malaria, Cholera, Dysentery

Justification: Central Nigeria receives a lot of rainfall and experiences flood frequently in the Benue River region. Flooding provides the best environment for breeding of mosquitoes that cause malaria. Floods also pollute source of water leading to cholera and dysentery which are common during the rainy season. These diseases are unfavourably enhanced by the unavailability of purified water, and proper sanitation in rural regions.

- Lagos/Rivers/Delta (South-South/South-West Nigeria)

Disease Outbreaks. Malaria, Cholera, Respiratory Illnesses

Justification: Most coastal states in southern region of Nigeria have been experiencing moderate coastal flooding and rising sea levels caused by climate change. Heavy rainfall in Lagos causes water stagnation in urban areas, which in turn causes malaria.

When rooms are crowded, drainage is inadequate, and contaminated water sources are involved during floods, cholera spreads easily. Also, the emissions from industries lead to respiratory diseases endemic in; asthma, bronchitis due to increased temperatures change seasonally because of climate change.

- South East (Enugu, Anambra, Ebonyi state)

Disease Outbreaks: Cholera, Malaria

Justification: There is flooding and landslides in eastern Nigeria particularly in riverine areas. Flooding can also spread sewerage into water sources and drinking water and thus cause a cholera outbreak. Also, water left behind after floods leads to breeding of mosquitoes that cause malaria epidemics. These climatic events are on the increase and are more severe due to climate change.

Cholera is associated with overcrowded housing, inadequate drainage systems, contaminated water supply during floods. Also, polluted air from industries also deepens respiratory diseases such as asthma and bronchitis due to seasonal changes in temperature as a result of climatic change.

From our findings, the growing urgency for comprehensive, climate-resilient health systems are needed. This is needed to address both immediate public health threats and long-term climate risks.

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Despite strides in Nigeria's healthcare system, it remains structurally challenged, particularly in rural and underserved areas, where funding and infrastructure are inadequate to respond effectively to climate-induced health emergencies. The weak disease surveillance systems, inadequate healthcare infrastructure, and lack of proactive planning have hindered the country's ability to build resilience against infectious disease outbreaks. As a result, the compounding effects of climate change have further undermined progress toward achieving Sustainable Development Goal 3, which aims to ensure healthy lives and promote well-being for all.

Finally, the intersection of climate change and public health in Nigeria underscores the urgent need for integrated approaches that address both climate adaptation and health policy. To mitigate the impacts of climate-driven infectious disease outbreaks, Nigeria must invest in strengthening its healthcare infrastructure, improving disease surveillance, and developing long-term resilience strategies. Addressing these challenges will not only protect the health of Nigeria's population but also contribute to regional and global health security, given Nigeria's pivotal role in West Africa. The lessons learned from Nigeria's experience offer valuable insights for other climate-vulnerable countries facing similar public health challenges.

LIMITATIONS

Despite the comprehensive nature of the data, there were some limitations. Rural regions of the country are under-resourced and as a result, reporting was less consistent causing gaps in historical records. This could also limit accuracy of trends over time. In addition, case definition standards and measurement techniques have evolved over the years resulting in varied recording and reporting standards. There is also the problem of underreporting of some disease cases such as malaria which is an endemic disease. This could skew data accuracy as some cases are unrecorded as people may not present to the hospital. Misdiagnosis is also a possibility especially in the earlier years when there were limited diagnostic facilities.

Confounding variables also have an impact in disease prevalence. Such factors include water and sanitation quality, migration and population density. While the study aims to correlate climate variables and disease outbreaks, it cannot definitely prove causation and this is another strong limitation.

Policy implications of our findings.

- Increase Healthcare Funding: Allocate at least 10% of GDP to healthcare by 2025 to improve infrastructure and capacity in climate-vulnerable regions. Funds from government revenue, internation aid and bonds can be set aside for the healthcare sector. Engaging financial experts to structure sustainable financing mechanism may also be beneficial. In addition, the government should prioritize funding for climate-vulnerable regions with the highest disease burden.
- Integrate Climate-Health Policies: By early 2025, more workshops should be conducted with public health, environmental and policy experts to outline climate adaptation strategies relevant to health. Legislative support is necessary and as such, a collaboration should be set up between the ministry of health and environment to draft policy recommendations that would be presented to parliament for enactment by 2026. Also, they should embed climate adaptation strategies into public health policies, focusing on building resilience in flood and drought-prone areas.
- Enhance Disease Surveillance: disease surveillance can be improved if data-sharing agreements are established with meteorological agencies to integrate real-time climate data into health surveillance by mid-2025. Research institutions should also develop predictive models that can forecast outbreaks based on weather patterns. It is also very important that training programs are set up for public health officials to enable them interpret the model predictions and implement preemptive measures.
- Improve Water and Sanitation Access: For any real improvement to be carried out, infrastructure audits must be conducted first to determine resilience needs. For example, conducting assessment of water systems in 10 flood-prone states by mid-2025. Partnering with civil engineering firms to design infrastructure to withstand flooding is therefore key and construction of pilot projects should begin by

2026. It is also paramount that regular maintenance schedules are established and resources allocated for ongoing infrastructure resilience improvement. Oversight committees can be set up in each state.

- Foster Public-Private Partnerships: Incentivize private investment in climate-smart healthcare technologies by 2025, targeting mosquito control and water sanitation innovations. Tax incentives, subsidies and grants can be given to private companies to encourage investment. A monitoring framework can also be setup to track the impact of these partnerships on disease incidence especially in areas of high-risk and adjusting incentives based on effectiveness.
- Strengthen Public Health Education: Launch nationwide campaigns by 2025 to raise awareness of climate-sensitive diseases, targeting at-risk communities with hygiene and mosquito control messaging. Community health workers in at-risk regions should be trained by 2025 to lead the awareness campaigns in their localities and distribute educational materials. Media and outreach channels such as radio, social media or community events can be used to reach remote population, maximize reach and effectiveness.
- Increase International Collaboration: Assemble teams to draft proposals that can help secure funding from global mechanisms (e.g., Green Climate Fund, world bank) to support Nigeria's climate-health initiatives with more focus on the specific needs of the country. Annual review meetings should be held to assess funding allocation and impact. Accountability can also be ensured by developing transparent monitoring and reporting frameworks to track progress on funded projects as this increases potential for renewed funding.
- Promote Climate-Health Research: Invest in research on climate-sensitive diseases and indigenous adaptation strategies.The Ministry of Health can establish a fund by 2025 to finance research on climate related issues. Research findings should also be published in open-access journals and shared with policymakers, and healthcare providers to influence future practices and policies.

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