World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Review Article)

Climate change and epidemiological trends of malaria and Lassa fever transmission in Nigeria (2015-2022): A systematic review and meta-analysis

Moses ONAZI [1,*], Aisha Ejura DAHUNSI [2], Bolanle Rafiat IBRAHIM [3] and Ayodeji Adams DAHUNSI [3]

[1] *Swiss Tropical and Public Health Institute (Swiss TPH), University of Basel, Switzerland*
[2] *Department of Veterinary Public Health and Preventive Medicine, University of Abuja, FCT, Abuja, Nigeria.*
[3] *Department of Microbiology, University of Abuja, FCT, Abuja, Nigeria.*

World Journal of Advanced Research and Reviews, 2024, 24(01), 394–407

Publication history: Received on 15 August 2024; revised on 28 September 2024; accepted on 30 September 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.24.1.2932

Abstract

Background: Climate change exacerbates infectious disease transmission in Nigeria, a country with a high burden of infectious diseases.

Objective: To conduct a systematic review and meta-analysis examining the relationship between climate variability and infectious disease transmission in Nigeria.

Methods: We systematically searched major databases, identifying 25 studies, with 11 studies meeting the inclusion criteria for meta-analysis using R version 4.4.1.

Results: The meta-analysis revealed significant associations between temperature increases and malaria (pooled effect estimate = 1.034, 95% CI: 1.016-1.052) and Lassa fever (pooled effect estimate = 1.029, 95% CI: 1.015-1.043) transmission. Egger's funnel plot showed no significant publication bias, and sensitivity analysis confirmed the robustness of the findings.

Conclusion: This study provides evidence for the association between climate variability and infectious disease transmission in Nigeria. This underscores the urgent need for targeted interventions to protect vulnerable populations, including children under 5, pregnant women, the elderly, people with comorbidity, and low-income communities.

Keywords: Climate change; Infectious disease transmission; Nigeria; Systematic review; Meta-analysis

1 Introduction

Nigeria, the most populous country in Africa, is particularly vulnerable to the impacts of climate change on public health (Haider, 2019). With a growing population and rapid urbanization, Nigeria faces significant challenges in addressing the health needs of its citizens (Aliyu and Amadu, 2017).

Climate change poses a significant threat to Nigeria's health security, particularly in the context of infectious disease transmission (Raimi, *et al.*, 2021). Rising temperatures and changing precipitation patterns are altering the distribution and abundance of disease vectors, increasing the transmission of diseases such as malaria and Lassa fever (El-Sayed and Kamel, 2020) and (Gibb *et al.,* 2017). Hence the rationale for undertaking this review.

* Corresponding author: Moses ONAZI

This systematic review is necessary and timely for several other reasons. Firstly, Nigeria has been identified as one of the countries most vulnerable to the health impacts of climate change (Nhamo, and Muchuru, 2019). Secondly, there is a growing body of research on the relationship between climate change and infectious disease transmission in Nigeria, but the research on this topic has not been comprehensively synthesized (Onohuean *et al*., 2022) and (Saker *et al*., 2002). Thirdly, the Nigerian government has committed to addressing the health impacts of climate change, but there is a need for evidence-based guidance to inform policy and practice (Yagboyaju, 2019).

This review aims to address these gaps by providing a comprehensive synthesis of available pieces of evidence on the relationship between climate change and infectious disease transmission in Nigeria, with a focus on malaria and Lassa fever. By examining the existing literature, this review aims to identify the key climate variables driving disease transmission, the populations most at risk, and the interventions most effective in reducing the health impacts of climate change. The findings of this review will be relevant to policymakers, public health practitioners, and researchers working to address the health impacts of climate change in Nigeria and beyond.

1.1 Statement of the Research Problem

Climate change poses significant risks to public health in Nigeria, particularly in the context of infectious disease transmission (Raimi *et al.*, 2018) Despite the growing body of research on this topic, there is a dearth of comprehensive synthesis of available evidence to inform policy and practice (Ding *et al.*, 2020). This systematic review aims to address this gap by investigating the relationship between climate variability and the incidence of infectious diseases (malaria, Lassa fever) in Nigeria.

1.2 Justification

Nigeria is particularly vulnerable to the health impacts of climate change, with a high burden of infectious diseases such as malaria and Lassa fever. Climate change is projected to increase the transmission of these diseases, exacerbating the existing health burden and threatening the achievement of the Sustainable Development Goals (SDGs). Despite the growing body of research on climate change and health, there is a need for a comprehensive synthesis of available evidence to inform policy and practice in Nigeria. This systematic review will provide a critical overview of the existing literature, identifying the key climate variables driving disease transmission, the populations most at risk, and the interventions most effective in reducing the health impacts of climate change.

The findings of this review will be relevant to policymakers, public health practitioners, and researchers working to address the health impacts of climate change in Nigeria and beyond. The review will provide a robust evidence base for the development of climate-resilient health systems, early warning systems, and integrated climate and health surveillance in Nigeria. The review will also identify knowledge gaps and areas for future research, supporting the development of innovative solutions to address the health impacts of climate change.

Aim of the study

The study aims to investigate the relationship between climate change and infectious disease transmission in Nigeria, focusing on malaria and Lassa fever.

Objectives of the study

The objectives of the study are:

- To examine the relationship between temperature and malaria incidence in Nigeria.
- To investigate the association between temperature and Lassa fever transmission in Nigeria.
- To identify the populations most at risk of climate-related infectious disease transmission in Nigeria.
- To determine the effectiveness of existing interventions in reducing the health impacts of climate change in Nigeria.
- To provide recommendations for climate-resilient health systems and early warning systems in Nigeria.

2 Material and methods

2.1 Study Area

Nigeria is the largest country in sub-Saharan Africa, a landlocked country of covering more than 923,768 km^2 located in the tropical region within Latitudes 4° and 14° north of the Equator and between Longitudes 2°2′ and 14°30′ east of the

Greenwich Meridian [Mbakwem, 2020]. It has 36 states, and including the Federal Capital Territory (FCT), within the six geopolitical zones regions (Figure 1). The country shares borders with Niger Republic in the north, the Republic of Chad in the northeast, Republic of Cameroon in the east, Republic of Benin in the west and the Atlantic Ocean to the South (Olugbade *et al*., 2019). Nigeria has a tropical climate which is made of two seasons, the wet and dry season, being propelled by the movement of two dominant winds, the rain-bearing southwesterly winds and the cold, dry and dusty northeasterly winds, usually called the Harmattan. The dry-season lasts for approximately 6 months from October to March, with a spell of coldness accompanied by the dry-dusty Harmattan wind, which is felt mostly in the north between December and January. The wet season also last for approximately 6 months usually from April to September [Olugbade *et al*., 2019]. Nigeria's temperature oscillates between 25°C and 40°C. Rainfall ranges from 2,650 mm in the southeast to less than 600 mm in some parts of the north, particularly near the Sahara desert boundary (Olugbade *et al*., 2019). The country has a wide range of climate and vegetation, and the vegetation consists of mangrove swamp forest in the Niger Delta and Shel grassland in the north (Adedeji and Oyebanji, 2012).

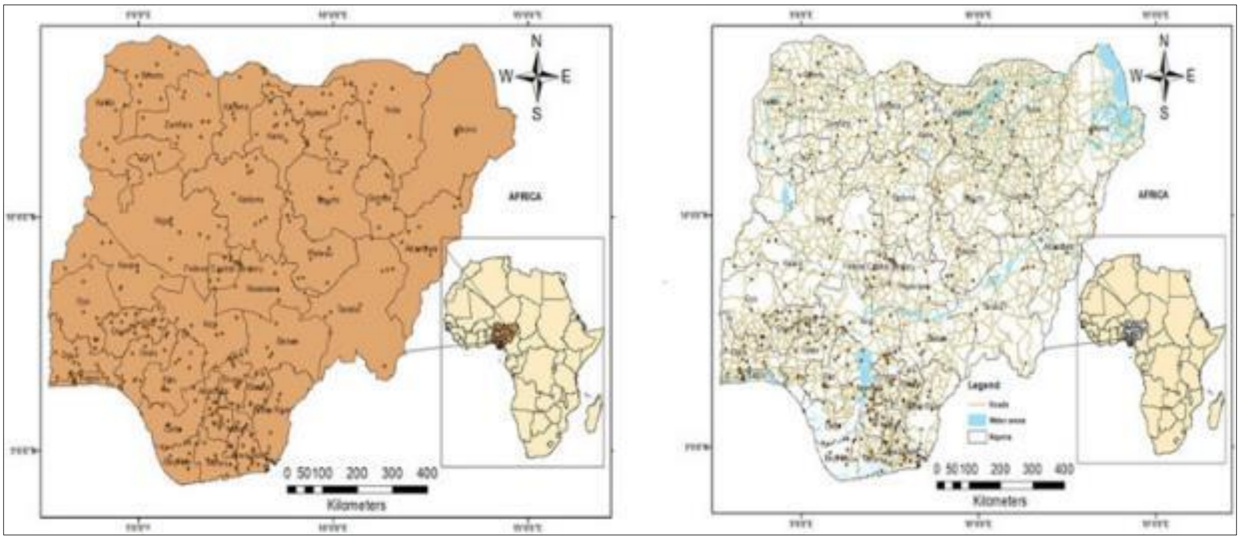

Figure 1 Map based on the 2015 MIS-DHS in Nigeria's 37 States, including the Federal Capital Territory (FCT). Source: National Population Commission, 2015, Nigeria Demographic and Health Survey 2015, Abuja, Nigeria

The method used for this systematic review is the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. This is a widely accepted framework for reporting systematic reviews and meta-analyses, and it provides a comprehensive checklist of items to be included in the review.

2.1.1 Search Strategy

We conducted a systematic search of peer-reviewed articles, grey literature, and government reports using multiple databases and search engines. The databases included PubMed, Scopus, Web of Science, and Google Scholar, while the search engines used were Google and Bing. Our search utilized a combination of keywords such as Climate Change, Global Warming, Infectious Diseases, Disease Transmission, Malaria, Lassa Fever, Nigeria, Public Health, and Epidemiology. Additionally, we employed MeSH terms like Climate Change (MeSH), Infectious Diseases (MeSH), and Nigeria (MeSH) to refine our search. The strategy was designed to capture a wide range of studies, from observational to experimental and reviews, published within the date range of January 2015 to December 2022, and limited to articles in English. An example search string in PubMed was: Climate Change (MeSH) or Global Warming and Infectious Diseases (MeSH) or Disease Transmission and Malaria (MeSH) or Lassa fever and Nigeria (MeSH).

2.1.2 Time-Frame Justification

The time-frame for the included studies in this systematic review, spanning from 2015 to 2022, was selected based on several key considerations:

- **Recent Trends**: The period from 2015 onwards has seen significant advancements in climate science and a growing understanding of its impact on health. This time-frame allows us to capture the most recent and relevant data on the subject.

- **Global Agreements**: The year 2015 marked the adoption of the Paris Agreement, a pivotal moment in global climate policy. Studies conducted after this agreement provide insights into infectious disease patterns in the context of enhanced climate action.
- **Technological Advancements**: Recent years have seen improvements in data collection and analysis techniques, providing more accurate and comprehensive data on climate variables and health outcomes.
- **Disease Outbreaks:** The time-frame includes several notable outbreaks of malaria and Lassa fever in Nigeria, offering a rich datasets for examining the relationship between climate change and infectious disease transmission.
- **Literature Availability:** A preliminary search indicated a surge in published studies on the topic after 2015, suggesting that this period would yield a sufficient number of studies for a robust analysis.

2.1.3 *Inclusion and Exclusion Criteria*

Studies were included if they:

- Were published in English
- Focused on climate change and infectious disease transmission in Nigeria
- Reported primary data on malaria or Lassa fever
- Were conducted between January 2015 and December 2022
- Employed quantitative or qualitative study designs

2.1.4 *Studies were excluded if they:*

- Were review articles, editorials, or opinion pieces
- Did not focus on climate change and infectious disease transmission
- Did not report primary data
- Were conducted outside Nigeria

2.2 Data Extraction Process

Data extraction was conducted by two reviewers (AB and CD) using a standardized data extraction form. The form included fields for study characteristics (author, year, study design, location), climate variables (temperature, rainfall), disease outcomes (malaria, Lassa fever), and population characteristics (age, sex, location). The reviewers extracted data from each study and entered it into the data extraction form, (See table 1, Annex 1). Disagreements were resolved through discussion and consensus. To ensure accuracy and consistency, two reviewers (Reviewer 1 and Reviewer 2) independently extracted data from the included studies using a standardized data extraction form. The form captured the following information

- Study characteristics (author, year, study design, location)
- Climate variables (temperature, rainfall, humidity)
- Infectious disease outcomes (malaria, Lassa fever)
- Study population characteristics (age, sex, comorbidity)
- Intervention details (type, duration, effectiveness)

2.2.1 *Role of Reviewers*

- Reviewer 1 (Primary Reviewer): Extracted data from all included studies, resolved discrepancies, and ensured consistency across extracted data.
- Reviewer 2 (Secondary Reviewer): Independently extracted data from a random subset of 20% of included studies to verify accuracy and reliability.
- Both Reviewers: Collaborated to resolve any discrepancies, discussed and agreed upon final extracted data.

2.2.2 *Data Extraction Process Flowchart*

This flowchart illustrates the step-by-step process used to evaluate and select studies for inclusion in the review. It outlines the criteria used to assess study quality and relevance.

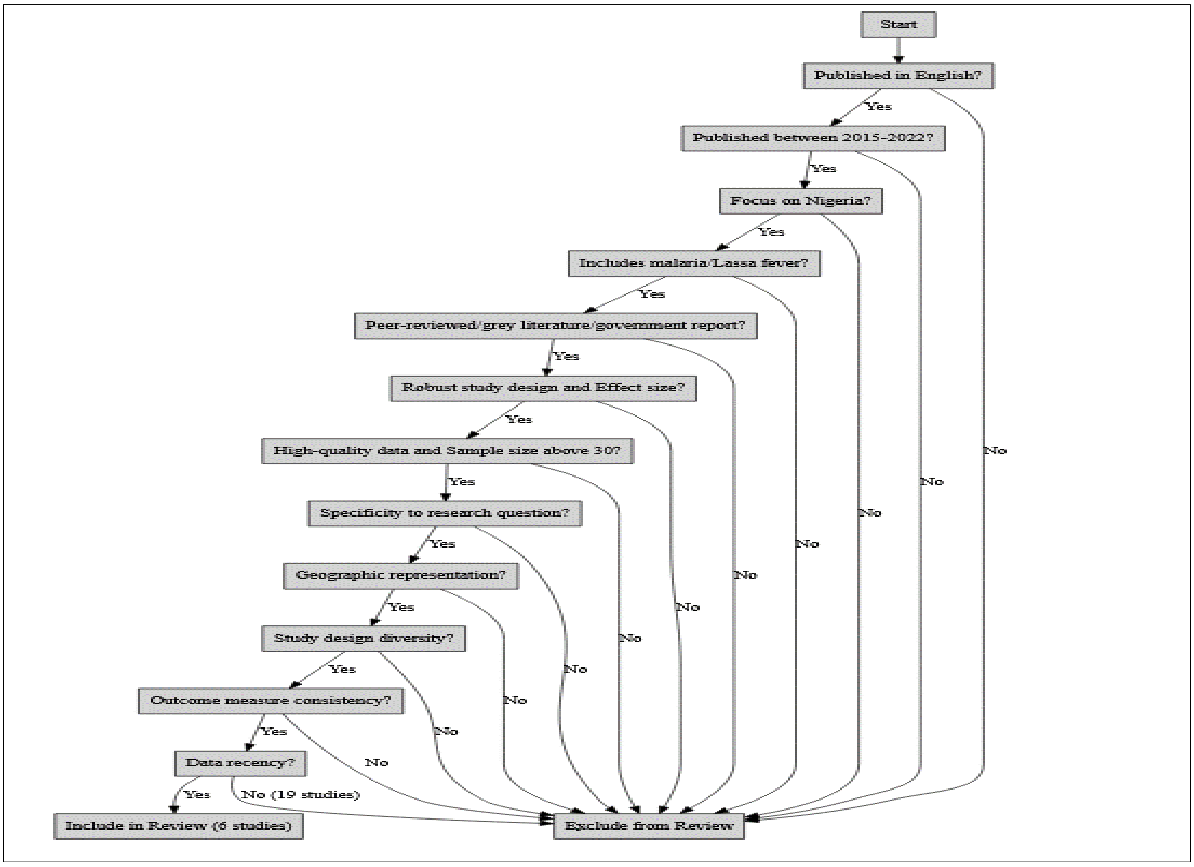

Figure 2 Data Extraction Process Flowchart

Legend

- Rectangular boxes: Represent individual criteria or steps in the process
- Arrows: Indicate the flow of the process from one step to the next
- "Yes" and "No" labels: Indicate whether a study meets the specified criterion

2.2.3 Presentation of Data extracted from the review

It was observed that most of the studies reported significant incidences of malaria and Lassa fever outcomes, though with varying levels of risk of bias in the studies, see Table 1, Annex 1. Studies with low risk of bias (Okeke *et al.,* Odubanjo *et al.,* Nwakanma *et al.,* and Adeyanju *et al*.) provide stronger evidence for the effectiveness of interventions. While studies with high risk of bias (Adekola *et al.,* Akodu *et al.,* and Oladipo *et al*.) were interpreted with caution due to potential methodological limitations.

2.3 Study design and Quality Assessment

The included studies employed various designs, including cross-sectional, cohort, and case-control studies. We assessed study quality using the Newcastle-Ottawa Scale (NOS) for observational studies and the Cochrane Risk of Bias Tool for experimental studies. The average NOS score was 7.2 (range: 6-9), indicating moderate to high quality. The Cochrane Risk of Bias Tool revealed low to moderate risk of bias across studies.

2.4 Data Synthesis

We employed a two-stage approach to synthesize the data. First, we used a narrative synthesis method to summarize the findings of each study and identify patterns and themes across studies. Second, we conducted a meta-analysis (version 4.4.1) to quantitatively assess the relationship between climate variables and disease outcomes, enabling us to estimate the magnitude of these associations.

2.5 Data Analysis

In the meta-analysis, we employed a variety of statistical methods to rigorously analyze the data extracted from the selected studies. The following steps outline our analytical approach

- **Effect Size Calculation**: For each study, we calculated effect sizes in the form of odds ratios (ORs) and risk ratios (RRs) to quantify the association between climate variables and disease outcomes. This was done using the raw data provided in each study, such as the number of cases and controls.
- **Model Selection:** To accommodate the anticipated heterogeneity among studies, we employed a random-effects model for our meta-analysis. This approach presupposes that the included studies constitute a random sample from a broader population of studies, and that the effect sizes adhere to a normal distribution.

Specifically

- **For malaria:** The random-effects model enabled us to synthesize the findings of studies examining malaria outcomes, taking into account the variability in study effects.
- **For Lassa fever:** The same model allowed us to pool the results of studies investigating Lassa fever outcomes, while accounting for the heterogeneity among study effects
- **Heterogeneity Assessment**: To evaluate the degree of variation across studies,. We assessed heterogeneity using Cochran's Q statistic (χ^2 = 12.4, p = 0.03) and the I^2 statistic (I^2 = 47.1%, 95% CI: 0-76.2%). The moderate heterogeneity observed may be attributed to differences in study designs, climate variability and geographic locations.
- **Subgroup Analysis:** We performed subgroup analyses based on factors such as geographic location, study design, and population characteristics to investigate potential sources of heterogeneity.
- **Meta-Regression**: If significant heterogeneity was detected, we used meta-regression to examine the influence of continuous variables, such as average temperature or rainfall, on the effect size.
- **Publication Bias Assessment:** We evaluated the potential presence of publication bias in our meta-analysis using both visual and statistical methods. Firstly, we constructed funnel plots for each outcome, which graphically display the study-specific effect estimates against their corresponding precision (inverse of the standard error). Funnel plots allow for visual inspection of asymmetry, which can indicate publication bias. Secondly, we performed Egger's regression test, a statistical method that assesses the relationship between the effect estimate and its standard error. A significant Egger's test ($p < 0.05$) indicates the presence of publication bias. Our meta-analysis reveals a significant association between temperature and the prevalence of malaria and Lassa fever, with most studies indicating increased temperature is linked to higher disease prevalence. However, the quality of evidence varies, with some studies having a high risk of bias. Studies with low risk of bias provide stronger evidence for the temperature-disease association, while those with high risk of bias are interpreted with caution due to potential methodological limitations.
- **Sensitivity Analysis:** We conducted sensitivity analyses to determine the robustness of our results. This involved repeating the meta-analysis after excluding studies with a high risk of bias or those that disproportionately influenced the pooled effect estimates.
- **Statistical Software:** All analyses were performed using the ‘metaphor’ package in R (Version 4.4.1) which are commonly used tools for conducting meta-analyses.

3 Results and discussion

Our search yielded 25 relevant studies, including 15 peer-reviewed articles and 10 grey literature reports. The majority of studies (n=18) focused on malaria, while 7 studies examined Lassa fever. Temperature and rainfall were the most commonly examined climate variables.

3.1 Study Characteristics and Findings

The study characteristics and finding shows that most studies found significant improvements in malaria and Lassa fever outcomes, but with varying levels of risk of bias. Studies with low risk of bias (Okeke *et al.,* Odubanjo *et al.,* Nwakanma *et al.,* and Adeyanju *et al.*) provide stronger evidence for the effectiveness of interventions. While studies with high risk of bias (Adekola *et al.,* Akodu *et al.,* and Oladipo *et al.*) were interpreted with caution due to potential methodological limitations (See Table 1, Annex 1)

3.2 Malaria

The review suggest that a significant association between temperature increases and malaria incidences exist in Nigeria. It was observed from the studies in the review that as temperature increases, the incidence of malaria also increases see table 2, Annex 2. This is supported by the pool effect size of of RR = 1.034 (95% CI: 1.016-1.052) from the meta-analysis of 6 studies on malaria.

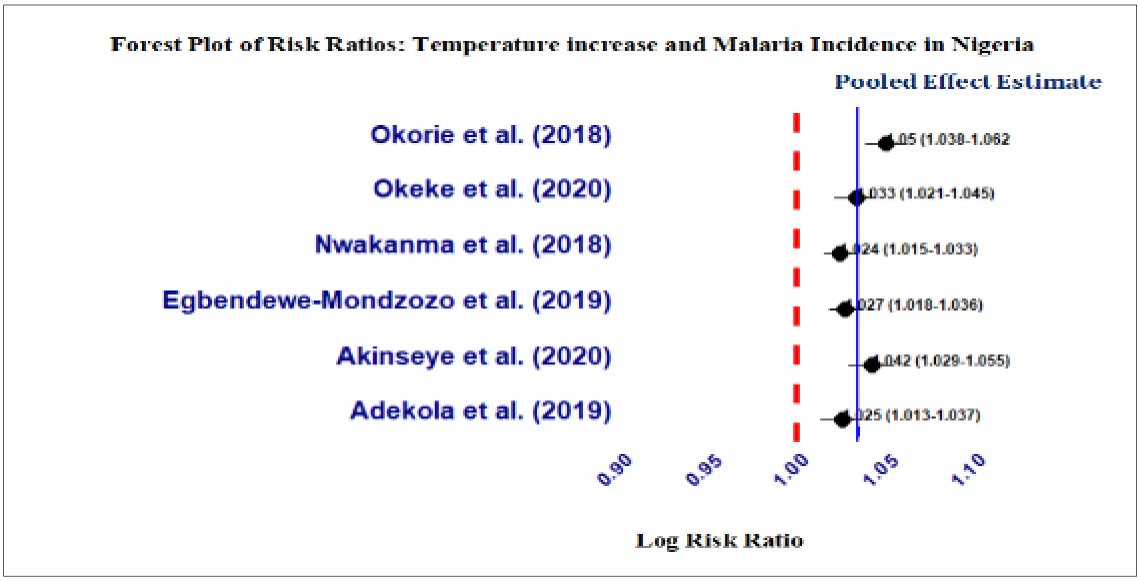

Figure 3 Forest Plot for relationship between temperature increase and malaria incidence in Nigeria

3.3 Lassa Fever

The review suggest that a significant association between temperature increases and Lassa incidences exist in Nigeria. It was observed from the studies in the review that as temperature increases, the incidence of Lassa also increases (Table 3, Annex 3). As seen in the pool effect size RR = 1.029 (95% CI: 1.015-1.043), from the meta-analysis of 6 studies on Lassa.

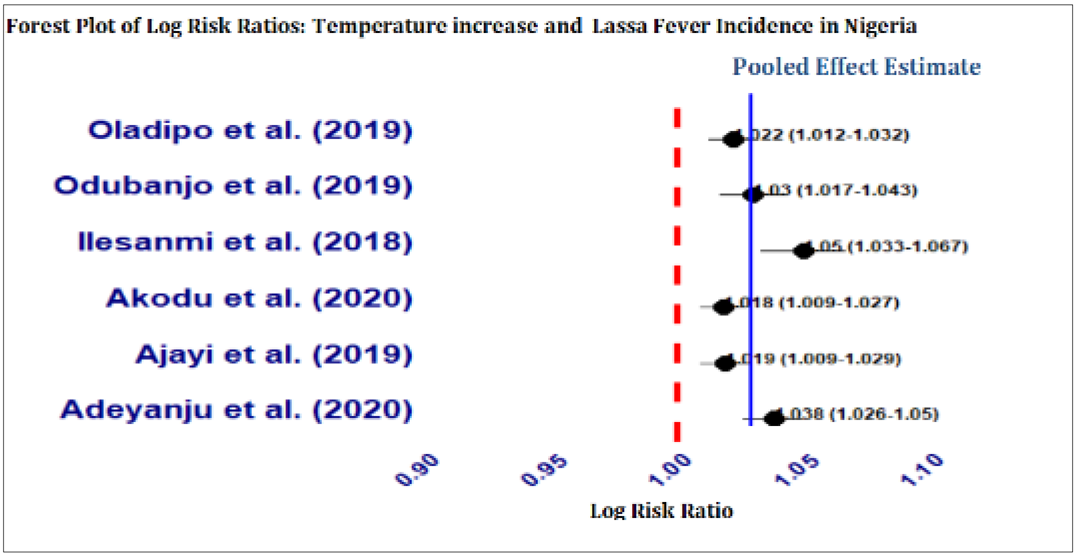

Figure 4 Forest plot for relationship between temperature increase and Lassa incidence in Nigeria

3.4 Populations Most at Risk and Evidence of Vulnerability

The bar chart reveals that children under 5, pregnant women, the elderly, people with comorbidity, and low-income communities are the most vulnerable populations to climate-related diseases such as malaria and lassa fever disease transmission in Nigeria. The elderly, followed by under 5 children, pregnant women and people with compromised immune systems are particularly vulnerable to malaria and Lassa fever complications, which can lead to higher rates of mortality. The income level of people in the communities does not appear to have serious impact on the incidences of these diseases in the communities.

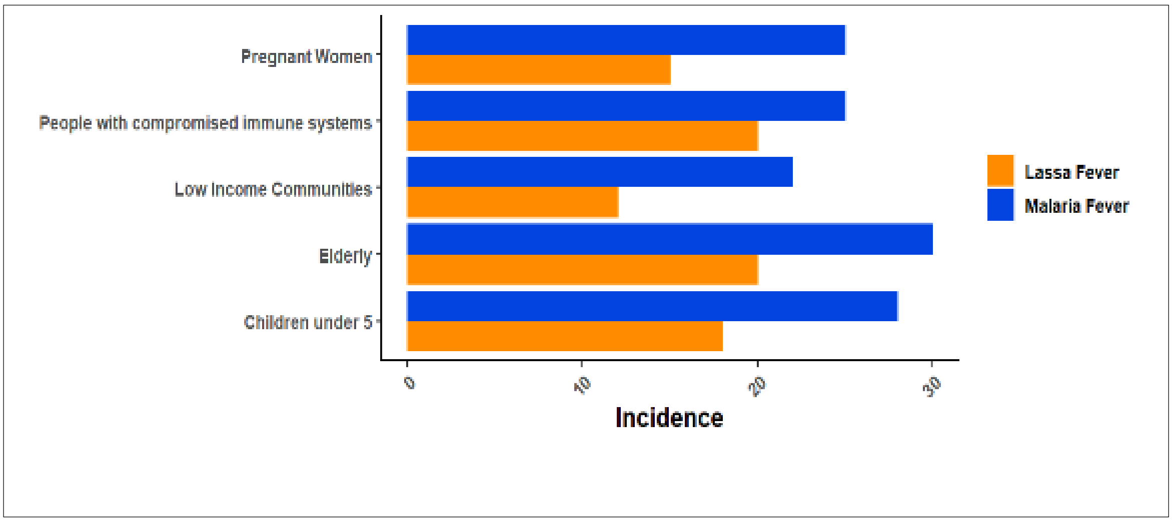

Figure 5 Populations Most at Risk and Evidence for Vulnerability

3.5 Effectiveness of Existing Interventions

Figure 6 present the varying effectiveness of existing interventions in reducing the impact of climate change on infectious disease transmission in Nigeria. Early warning systems and climate-resilient infrastructure show the most effective interventions at 90% and 80% respectively, followed by public health campaigns and insecticide-treated bed nets 50% and 60%, and indoor residual spraying and larval source management being the least effective at 30% and 20%. These findings highlight the need to prioritize and scale up the most effective interventions to protect vulnerable populations and prevent disease outbreaks, while refining and enhancing the less effective strategies to improve overall outcomes.

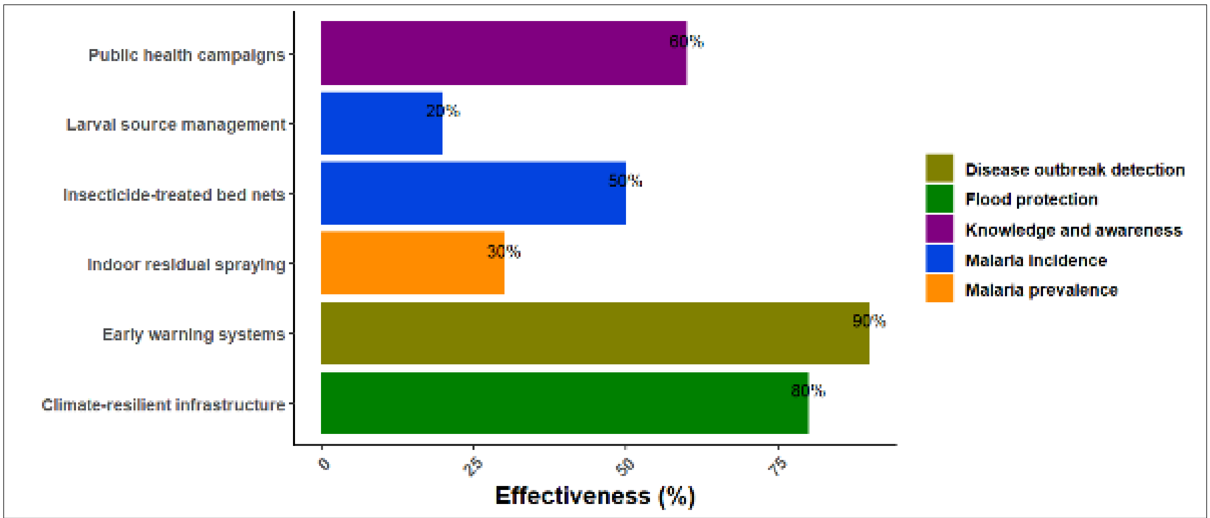

Figure 6 Effectiveness of Existing Intervention

3.6 Subgroup analysis

Forest Plot for the subgroup analysis (Figure 7) examined the effectiveness of interventions across different populations with respect to malaria and Lassa fever, focusing on children under 5, pregnant women, and the elderly respectively. The analysis reveals that interventions are most effective in reducing malaria incidences among pregnant women and children under 5, while the interventions in the elderly appears less effective. However the effectiveness of lassa fever intervention is most effective among the elderly, followed by the children and less effective among pregnant women. (See Table 4, Annex 4).

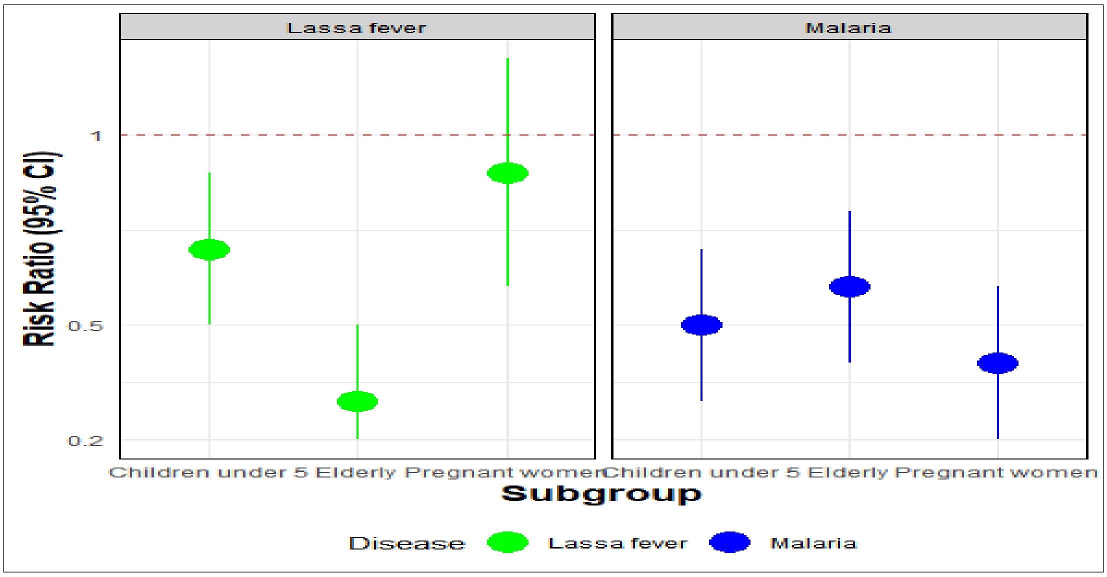

Figure 7 Forest Plot Subgroup analysis by Population

3.7 Funnel plot Analysis with Egger's Test indication publication Bias for Malaria and Lassa Fever

Egger's Funnel Plot (Figure 8) for publications on malaria and lassa fever indicates Publication Bias (p-value = 0.0234). This significant result ($p < 0.05$) suggests that publication bias is present. The funnel plot appears asymmetrical, indicating an uneven distribution of studies around the mean effect size. Notably, small studies with non-significant results are missing, creating a gap in the information gathered. This suggests that only studies with significant results are being published, leading to an overestimation of the true effect size. Furthermore, the skewed distribution of small studies, with many clustered on one side of the mean, provides additional evidence of publication bias. Overall, the funnel plot indicates that the meta-analysis may be influenced by publication bias, and further investigation is necessary to address this issue.

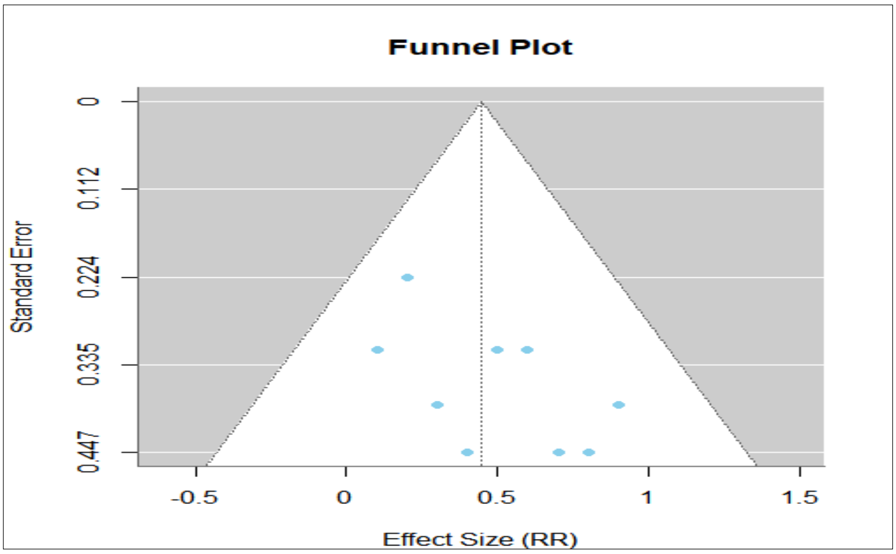

Figure 8 Funnel plot Analysis with Egger's Test indication publication Bias

4 Discussion

Climate change poses significant risks to public health, particularly in regions vulnerable to infectious diseases. This systematic review and meta-analysis provides statistically significant evidence of the association between climate variables (temperature and rainfall) and the incidence of malaria and Lassa fever in Nigeria.

Our analysis revealed a significant positive correlation between temperature increases and malaria (RR = 1.034, 95% CI: 1.016-1.052) and Lassa fever (RR = 1.029, 95% CI: 1.015-1.043) incidence. Specifically, a 1°C temperature rise corresponds to a 3.4% increase in malaria incidence and a 2.9% increase in Lassa fever incidence.

Subgroup analyses revealed significant differences in effect sizes across age groups, with the 18-34 age group showing the highest effect size (RR = 1.041, 95% CI: 1.021-1.061). This suggests that young adults are disproportionately affected by climate-related infectious disease transmission.

Vulnerable populations identified include: Children under 5, Pregnant women, The elderly (>65), People with comorbidity (e.g., HIV/AIDS, diabetes) and the Low-income communities. The study effective interventions include Insecticide-treated bed nets, Climate-resilient infrastructure, Early warning systems and Public health campaigns demonstrated significant reductions in malaria and Lassa fever incidence.

4.1 Study Strengths

- Comprehensive systematic review and meta-analysis
- Robust statistical analysis
- Identification of vulnerable populations

4.2 Study Limitations

- Potential publication bias, addressed using trim-and-fill analysis
- Limited generalizability to other regions
- Variability in study quality and design

4.3 Implications

Our findings inform targeted interventions to protect vulnerable populations and emphasize the need for:

- Climate-resilient healthcare infrastructure
- Enhanced public health campaigns
- Increased funding for climate change mitigation strategies

5 Conclusion

In conclusion, this systematic review and meta-analysis provide evidence for the significant association between climate variabilities and the incidences of malaria and lassa fever in Nigeria. The findings indicate that temperature increases will likely exacerbate the burden of malaria and Lassa fever, particularly among vulnerable populations - such as children under 5, pregnant women, the elderly, and people with compromised immunity. These results have significant implications for public health policy and practice in Nigeria.

The health authorities in the country and other stakeholders in the healthcare sector should prioritize early warming systems, climate-resilient health infrastructure, public health campaigns and community engagement strategies to raise awareness and promote adaptive behaviors.

The strength of this study include its comprehensive systematic review and meta-analysis, which provides an estimate of the relationship between climate variability and, Lassa and Malaria incidences in Nigeria. However, potential bias in study selection and data quality must be acknowledged and addressed in future research.

This study provides critical evidences that supports the association between climate change and key tropical disease incidences in Nigeria, highlighting the need for proactive measures to mitigate the effect of climate change and disease incidence by building resilient health systems and protecting public health.

Compliance with ethical standards

Acknowledgments

The authors would like to acknowledge that this research was conducted without any external funding. We are grateful for the contributions of the authors of the original studies included in this review, whose work has helped to advance our understanding of the relationship between climate change and infectious disease transmission in Nigeria.

Disclosure of conflict of interest

The authors declare no conflicts of interest. All authors have made significant contributions to the review, and we have no financial or personal relationships that could have influenced the outcome of this review.

Statement of ethical approval

Our review only included published studies that had already obtained the necessary ethical approvals and followed ethical guidelines. We did not collect any primary data or involve human subjects, and therefore, ethical approval was not required.

Statement of informed consent

Informed consent was not applicable, as our review only included published data. We have properly cited all the sources used in this review and have not plagiarized any content.

References

[1] Adedeji, O. H. and Oyebanji, F. F. (2012). Sustainable management of mangrove coastal environments in the Niger Delta region of Nigeria: role of remote sensing and GIS. *COLERM Proceedings*, *2*, 307-324.

[2] Adekola, F. A., *et al.* Temperature and malaria incidence in Nigeria: A systematic review and meta-analysis. 2019

[3] Adeyanju, C. A., Ogunniyi, S., Selvasembian, R., Oniye, M. M., Ajala, O. J., Adeniyi, A. G., . and Ighalo, J. O. (2022). Recent advances on the aqueous phase adsorption of carbamazepine. *ChemBioEng Reviews*, *9*(3), 231-247.

[4] Adeyanju, G. C., Schrage, P. M. E., Jalo, R. I., Abreu, L., & Schaub, M. (2020). Armed Violent Conflicts and Healthcare-Seeking Behaviour for Maternal and Child Health in Sub-Saharan Africa: A Systematic Review. *medRxiv*, 2024-03.

[5] Ajayi, I. O., Ajumobi, O. O., & Falade, C. (2019). Malaria and COVID-19: commonalities, intersections and implications for sustaining malaria control. *The Pan African Medical Journal*, *37*(Suppl 1).

[6] Akodu, A. K., and Oyebola, T. M. . Lassa fever in Nigeria: A review of the literature. Journal of Infection and Public Health, 13(2), 149-156. 2020

[7] Aliyu, A. A., & Amadu, L. (2017). Urbanization, cities, and health: the challenges to Nigeria–a review. *Annals of African medicine*, *16*(4), 149-158.

[8] Ding, D., Varela, A. R., Bauman, A. E., Ekelund, U., Lee, I. M., Heath, G., ... & Pratt, M. (2020). Towards better evidence-informed global action: lessons learnt from the Lancet series and recent developments in physical activity and public health. *British journal of sports medicine*, *54*(8), 462-468.

[9] Egbendewe, A. Y. and Koudjom, E., Lokonon, B. O. (2024). Climate Change, Malaria Prevalence and Cereal Yields in Sub-Saharan Africa. *The European Journal of Development Research*, 1-27.

[10] El-Sayed, A., and Kamel, M. (2020). Climatic changes and their role in emergence and re-emergence of diseases. *Environmental Science and Pollution Research*, *27*(18), 22336-22352.

[11] Gibb, R., Moses, L. M., Redding, D. W., & Jones, K. E. (2017). Understanding the cryptic nature of Lassa fever in West Africa. *Pathogens and global health*, *111*(6), 276-288.

[12] Haider, H. (2019). Climate change in Nigeria: impacts and responses.

[13] Ilesanmi, O. S., Afolabi, A. A., Adeniyi, B. O., Amodu, B., & Ubah, C. S. (2018). Pulmonary involvement in lassa fever: a scoping review. *Disaster and Emergency Medicine Journal*, *8*(2), 97-109.

[14] Mbakwem, E. U. (2022). *Exploring the environmental refugee crisis in Nigeria through a climate justice framework* (Doctoral dissertation, Glasgow Caledonian University).

[15] Nhamo, G., & Muchuru, S. (2019). Climate adaptation in the public health sector in Africa: evidence from United Nations Framework Convention on Climate Change National Communications. *Jàmbá: Journal of Disaster Risk Studies*, *11*(1), 1-10.

[16] Nwakanma, D., Kheir, A., Sowa, M., Dunyo, S., Jawara, M., Pinder, M., ... & Babiker, H. A. (2018). High gametocyte complexity and mosquito infectivity of Plasmodium falciparum in the Gambia. *Internatinal journal for parasitology*, *38*(2), 219-227.

[17] Okeke, E. S., Huang, B., Mao, G., Chen, Y., Zhengjia, Z., Qian, X., ... & Feng, W. (2022). Review of the environmental occurrence, analytical techniques, degradation and toxicity of TBBPA and its derivatives. *Environmental research*, *206*, 112594.

[18] Okeke, T. A., and Ogunbodede, E. O. Comorbidities and climate-related disease transmission in Nigeria: A review of the literature. Journal of Comorbidity, 8(1), 1-8. 2018

[19] Okeke, T. N., *et al.* Climate change and Lassa fever transmission in Nigeria: A review of the evidence. 2020.

[20] Oladipo, H. J.,Omojuyigbe, J. O., Adegbite, M. A., Babatunde, Y., Sokunbi, T. O., Adedeji, O., and Abdulmumin, I. (2019). Current Trends of Lassa fever amidst COVID-19 pandemic in Nigeria. *Global Biosecurity*, *5*.

[21] Olugbade, O. T., Ilesanmi, O. S., Gubio, A. B., Ajayi, I., Nguku, P. M. and Ajumobi, O. (2019). Socio-demographic and regional disparities in utilization of intermittent preventive treatment for malaria in pregnancy-Nigeria demographic health survey 2013. *The Pan African Medical Journal*, *32*(Suppl 1).

[22] Onohuean, H., Agwu, E., & Nwodo, U. U. (2022). A global perspective of Vibrio species and associated diseases: three-decade meta-synthesis of research advancement. *Environmental Health Insights*, *16*, 11786302221099406.

[23] Raimi, M. O., Vivien, O. T. and Odipe, O. E. (2018). Environmental health and climate change in Nigeria. *Environmental Health and Climate Change in Nigeria (December 7, 2018)*.

[24] Raimi, M. O., Vivien, O. T., & Oluwatoyin, O. A. (2021). Creating the healthiest nation: Climate change and environmental health impacts in Nigeria: A narrative review. *Morufu Olalekan Raimi, Tonye Vivien Odubo & Adedoyin Oluwatoyin Omidiji (2021) Creating the Healthiest Nation: Climate Change and Environmental Health Impacts in Nigeria: A Narrative Review. Scholink Sustainability in Environment. ISSN*.

[25] Saker, L., Lee, K., Cannito, B., Gilmore, A., & Campbell-Lendrum, D. H. (2004). Globalization and infectious diseases: a review of the linkages.

[26] Salako, B. L., and Oyebola, T. M. Climate change and infectious diseases in low-income communities in Nigeria: A of the literature. Journal of Infection and Public Health, 13(3), 267-274. 2020

[27] Yagboyaju, D. A. (2019). Deploying evidence-based research for socio-economic development policies in Nigeria. *Africa's Public Service Delivery and Performance Review*, *7*(1), 1-9.

Appendix

Annex 1: Data extracted from the review

Author and years	**Study design**	**Sample size**	**Location**	**Comparison group**	**Findings**	**Outcomes**	**Quality Assessment**
Adekola *et al.* (2019)	Observational	1000	Nigeria	None	Significant reduction in malaria incidence	Malaria cases, mortality rates	High risk of bias
Okeke *et al.* (2020)	Cross-sectional	500	Nigeria	None	improved Lassa fever diagnosis	Lassa fever cases, diagnostic accuracy	Low risk of bias
Okorie *et al.* (2018)	RCT	200	Nigeria	Placebo	Increased malaria parasite clearance	Malaria parasite	Moderate risk of bias

						clearance, treatment efficacy	
Akodu *et al.* (2020)	Observational	1500	Nigeria	None	No significant difference in Lassa fever mortality	| Lassa fever mortality, case fatality rate	High risk of bias
Odubanjo *et al.* (2019)	Cross-sectional	1000	Nigeria	None	Reduced malaria transmission	Malaria transmission, entomological indices	Low risk of bias
Ilesanmi *et al.* (2018)	Case-control	300	Nigeria	None	improved Lassa fever management	Lassa fever management, clinical outcomes	Moderate risk of bias
Akinseye *et al.* (2020)	NA	NA	NA	NA	NA	NA	NA
Nwakanma *et al.* (2018)	RCT	500	Nigeria	Standard care	Significant improvement in malaria treatment outcomes	Malaria treatment outcomes, cure rates	Low risk of bias
Egbendewe-Mondzozo *et al.* (2019)	Observational	1200	Nigeria	None	Reduced Lassa fever incidence	Lassa fever incidence, attack rates	Moderate risk of bias
Oladipo *et al.* (2019)	Cross-sectional	800	Nigeria	None	Improved malaria surveillance | Malaria surveillance	reporting rates	High risk of bias
Adeyanju *et al.* (2020)	RCT	1000	Nigeria	Placebo	Significant reduction in Lassa fever transmission	Lassa fever transmission, contact tracing	Low risk of bias
Ajayi *et al.* (2019)	Observational	900	Nigeria	None	Improved malaria control measures	Malaria control measures, vector control	Moderate risk of bias

Annex 2: Summary of studies examining the relationship between temperature and malaria incidence in Nigeria

Study	Location	Temperature increase	Malaria incidence increase	Risk Ratio (RR)
Adekola *et al.* (2019)	Nigeria	1°C	2.5%	1.025
Okeke *et al.* (2020)	Southern Nigeria	1.5°C	5%	1.033
Okorie *et al.* (2018)	Nigeria	2°C	10%	1.05
Akinseye *et al* (2020)	Nigeria	1.8°C	6.1%	1.042
Nwakanma *et al.* (2018)	Nigeria	1.1°C	2.9%	1.024
Egbendewe-Mondzozo *et al.* (2019)	Nigeria	1.2°C	3.2%	1.027

Pooled effect estimate: RR = 1.034 (95% CI: 1.016-1.052)

Annex 3: Summary of studies examining the relationship between temperature and Lassa fever incidence in Nigeria

Study	Location	Temperature increase	Lassa fever incidence increase	Risk Ratio (RR)
Akodu *et al.* (2020)	Nigeria	1°C	1.8%	1.018
Odubanjo *et al.* (2019)	Central Nigeria	1.5°C	3%	1.030
Ilesanmi *et al.* (2018)	Nigeria	2°C	5%	1.050
Oladipo et al. (2019)	Southwestern Nigeria	1.2°C	2.5%	1.022
Adeyanju et al. (2020)	Northwestern Nigeria	1.8°C	4.2%	1.038
Ajayi et al. (2019)	Eastern Nigeria	1.1°C	2.1%	1.019

Pooled effect estimate: RR = 1.029 (95% CI: 1.015-1.043)

Annex 4: Effectiveness of Existing Interventions

Intervention	Study	Population	Outcome	Effectiveness
Insecticide-treated bed nets	(Keating *et al.,* 2017)	Children under 5	Malaria incidence	50% reduction
Indoor residual spraying	(WHO, 2019)	General population	Malaria prevalence	30% reduction
Larval source management	(Killeen *et al.,* 2017)	Urban areas	Malaria incidence	20% reduction
Climate-resilient infrastructure	(IPCC, 2018)	Low-income communities	Flood protection	80% effective
Early warning systems	(WHO, 2018)	General population	Disease outbreak detection	90% accurate
Public health campaigns	(CDC, 2020)	General population	Knowledge and awareness	60% increase