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Review Article

Diverse Pathways of Climate Changes and Environmental Factors on Tuberculosis and Infectious Diseases

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Abstract: The effects of changes in climatic factors like temperature, moisture, and precipitation influence host response through differences in vitamin D distribution, ultraviolet radiation, malnutrition, and other risk factors. This paper proposes a conceptual framework for the impact of climate change on tuberculosis through diverse pathways. The results of the analysis show a pathway's relationship between the environment, tuberculosis (TB) risk time, and social fabric is represented in the social environment; place vulnerability is an example of the built environment, the hazard potential functions through both the social and natural environment, while geographic context focuses on the natural aspects of the environment. Notwithstanding, environmental factors and infectious diseases, especially tuberculosis, have a complicated and multidimensional interaction. The synthesis of the previous studies and conceptual model of this paper, along with additional literature, underscores the need for public health strategies that incorporate environmental factors. The paper concludes that as climate change continues to shape global health landscapes, there is an urgent need for policies and interventions that address the complex interactions between climate, geography, and disease. Future research should continue to explore these relationships, as well as develop actionable insights for mitigating the public health impacts of climate-driven disease transmission. It is envisaged that this theoretical model will serve as a useful tool in identifying and addressing the gap, which consequently has long-term benefits on the risk factors for tuberculosis.

Keywords: Tuberculosis, Climate Change, Environmental Factors, Infectious Diseases.

INTRODUCTION

The Global tuberculosis report (2018) reveals that Tuberculosis (TB) is contagious and airborne. Furthermore, TB was one of the top leading 10 causes of death worldwide in 2017. It is additionally the leading killer of individuals with HIV and a serious reason for deaths associated with antimicrobial resistance. The World Health Organization (WHO) declared TB a world emergency in 1993 and it remains one amongst the world's major causes of health problem and death.

According to a 2017 global report by the World Health Organization (WHO), it is estimated that two out of every 1,000 Nigerians have TB yearly. This is an estimated figure; the actual figure might be scarier. Nigeria has the sixth highest burden of TB patients globally and the first in Africa and it should be noted that tuberculosis is one of the top 10 causes of deaths and that Nigeria is classified among 30 countries with high burden of TB, Multi-Drug Resistant TB (MDR-TB) and TB/HIV.

Poor health care delivery systems and lack of adequate research are two major factors associated with the increasing casualties and deaths among large number of populations in the country.

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Figure 1: Map of Nigeria

Figure 2: Example of TB Patient

Nigeria is ranked fourth globally and first in Africa among high-burden TB countries in the globe. However, according to Ibrahim *et al*., (2015), due to insufficient knowledge on the disease prevalence and its spatial domain, it is extremely difficult for the government to identify areas of high risk, and where due attention should be focused to provide the needed policies to address the issues. To do this, evidence -based information needs to be established using analytical procedures to support this decision. One such innovative methodology is through the use of Geographical Information Systems (GIS), a powerful tool commonly used in health research to inform policy. The availability of GIS along with the proliferation of disaggregated data

provides the idea situation for studies that of disease risk mapping, cluster and spatial pattern analysis. The use of GIS in disease mapping will attempt to understand and recognize spatial patterns to understand its degree of distribution and prevalence, and consequently factors associated with and responsible for the observed patterns (Oluwoye, 2001). An understanding of these patterns is crucial for the development and implementation of novel approaches and strategies for the disease risk modelling, prevention and management.

An Overview of the State of the Art

Infectious diseases are deeply influenced by environmental and climatic factors, a link that has increasingly gained attention in the context of global health. To Shi, D, *et al*., "Tuberculosis (TB), a respiratory disease brought on by Mycobacterium tuberculosis, is a public health issue, particularly in low- and middle-income countries (LMICs)." The environment, particularly temperature, altitude, and more general climate-related changes, have been shown in numerous studies to have a major impact on the dynamics of tuberculosis transmission (Gelaw *et al*., 2022; Uwishema *et al*., 2023). The epidemiology patterns of many infectious diseases are predicted to shift as a result of climate change, which has caused global warming, changed precipitation patterns, and extreme weather events. This event will present difficulties for healthcare systems around the world (Uwishema *et al*., 2023). Two pivotal studies—Gelaw *et al*., (2022) and Uwishema *et al*., (2023)—explore the relationships between environmental factors and infectious diseases. Gelaw *et al*., (2022) conduct a systematic review of existing literature to assess how fever and altitude impact TB notification rates. Meanwhile, Uwishema *et al*., (2023) discuss how climate changes could influence the prevalence and transmission of various infectious diseases, including TB. This literature review synthesizes the findings of these studies and integrates additional research to offer a comprehensive understanding of how environmental and climatic factors influence TB and other infectious diseases.

Review of Primary Studies, 1. Effect of Temperature and Altitude on Tuberculosis Notification (Gelaw *et al*., 2022) Gelaw *et al*., (2022) conducted a systematic review to assess the impact of temperature and altitude on TB notification rates. Using data from studies conducted in various regions, the authors sought to identify patterns in TB transmission and incidence that correlate with variations in temperature and altitude. The methodology involved selecting peer-reviewed articles that examined these environmental factors, providing a meta-analysis of the association between TB notification and environmental conditions. The review by Gelaw *et al*., (2022) concluded that TB notifications tend to increase in lower-altitude, warmer regions. Specifically, higher temperatures seem to correlate positively with TB transmission, as warmer conditions may promote bacterial survival and increase human interactions, which can promote the spread of TB. On the other hand, lower TB notice rates were linked to cooler temperatures at higher elevations, indicating that altitude-related factors, like lower temperatures and lower oxygen levels, may hinder the bacterium's capacity to spread and survive. Gelaw *et al*., also highlight potential socioeconomic confounders, as individuals residing at higher altitudes often have different socioeconomic statuses, which could influence health outcomes and TB exposure. The study recommends that future TB control strategies take into account geographic and environmental factors, as targeted interventions could help reduce TB incidence in areas with high transmission risk due to favorable climatic conditions for the bacteria.

2. *Impacts of Environmental and Climatic Changes on Future Infectious Diseases* (Uwishema *et al*., 2023) Uwishema *et al*., (2023) take a broader approach, examining how climate change and environmental alterations might affect the spread of infectious diseases, including TB. This paper is a comprehensive review that considers various climate-related factors—such as temperature increases, altered precipitation, and extreme weather events—and how these changes could impact disease dynamics globally. Unlike Gelaw *et al*., who focus on TB in relation to altitude and temperature, Uwishema *et al*., (2023) look at a wider range of infectious diseases, discussing how climate shifts are likely to influence disease vectors, pathogen survival, and host interactions. The authors find that rising global temperatures and humidity levels could create more hospitable environments for pathogens, while also altering the geographic distribution of vector-borne diseases like malaria and dengue. For TB specifically, Uwishema *et al*., suggest that urban areas experiencing warmer and more humid climates may see increased TB transmission, as overcrowding and temperature shifts favor bacterial persistence and human-to-human transmission. This study emphasizes the need for climate-resilient healthcare systems and policies that consider the looming threat of climate-induced infectious disease spread. *Comparative Analysis of Primary Studies* Both Gelaw, *et al*., (2022) and Uwishema *et al*., (2023) address the intersection of environmental conditions and infectious diseases, yet they use different scopes and methodologies. Gelaw *et al*., (2022) focus on a systematic review of TB notifications, providing a quantitative perspective on how temperature and altitude impact TB specifically. Their findings align with previous studies indicating that TB thrives in warmer climates and lower altitudes, where environmental conditions are more favorable for the bacterium's survival and spread (Chan *et al*., 2018; Zhu *et al*., 2019). The study's focus on his, her, their, etc. altitude and temperature presents a specific lens for understanding TB epidemiology, highlighting geographic areas where public health interventions may be especially needed. In contrast, Uwishema *et al*., (2023) provide a broader review, addressing climate change's potential impact on a variety of infectious diseases. Their work emphasizes the broader implications of climate-related changes, such

as rising temperatures and humidity, on disease dynamics. They argue that climate change could exacerbate not only TB but also vector-borne diseases like malaria and respiratory illnesses, stressing the interconnectedness of climate and disease (Carroll *et al.*, 2017). By exploring multiple diseases, Uwishema *et al*., underscore the need for an integrated response that considers the diverse ways in which climate change may affect global health. Despite their differences, both studies agree on the necessity of integrating environmental factors into infectious disease management. Gelaw *et al.,* (2022) suggest targeted TB control in low-altitude and warmer regions, while Uwishema *et al*., (2023) advocate for climate-resilient healthcare policies that address a wider range of diseases. Together, these studies provide a well-rounded perspective on the importance of environmental considerations in managing infectious disease threats. ***Supporting Literature***, Additional studies support and expand on the findings of Gelaw *et al*., (2022) and Uwishema *et al*., (2023). For example, research by Zhu *et al.,* (2019) confirms the positive correlation between warmer temperatures and TB incidence, noting that temperature influences both bacterial viability and human exposure patterns. Another study by Altizer *et al*., (2013) supports Uwishema *et al.*'s claims about the broader impacts of climate change on infectious diseases, observing that climate-induced shifts in vector distribution have led to the re-emergence of diseases in previously unaffected areas. Research by Cobos-Medina *et al.,* (2021) further substantiates the altitude-temperature relationship in TB transmission, suggesting that high-altitude areas may have natural protective effects against TB due to factors such as lower air density and cooler temperatures. This finding aligns with Gelaw *et al.*'s observation that high-altitude regions typically exhibit lower TB notification rates. Meanwhile, a study by Escobar *et al*., (2016) reinforces Uwishema *et al.*'s conclusion that climate change may increase disease burden globally, especially in urban areas where overcrowding and warming climates could enhance pathogen spread. *Implications for Public Health and Policy* The insights gained from Gelaw *et al*., (2022), Uwishema *et al*., (2023), and supporting literature have significant implications for public health. For TB, public health agencies could develop geographically tailored interventions that focus on high-risk, low-altitude, and warmer regions. This event might include expanding TB screening and treatment services in these areas, as well as conducting more research on how environmental factors influence TB (World Health Organization, 2020). Given the broader scope of climate impacts on infectious diseases, Uwishema *et al*., (2023) advocate for integrated, climate-resilient health policies that can respond to a range of emerging threats. Climate change adaptation strategies could include establishing early-warning systems for infectious disease outbreaks, investing in research on climate-health interactions, and prioritizing healthcare resources in regions most vulnerable to climate change. As Carroll *et al*., (2017) suggest international collaboration will be crucial in managing climate-related health risks, as infectious diseases do not cohere to national boundaries.

Development of Conceptual Model of Climate impacts on Tuberculosis through Diverse Pathways and Analysis

The effects of changes in climatic factors like temperature, moisture, and precipitation influence host response through differences in vitamin D distribution, ultraviolet radiation, malnutrition, and other risk factors.

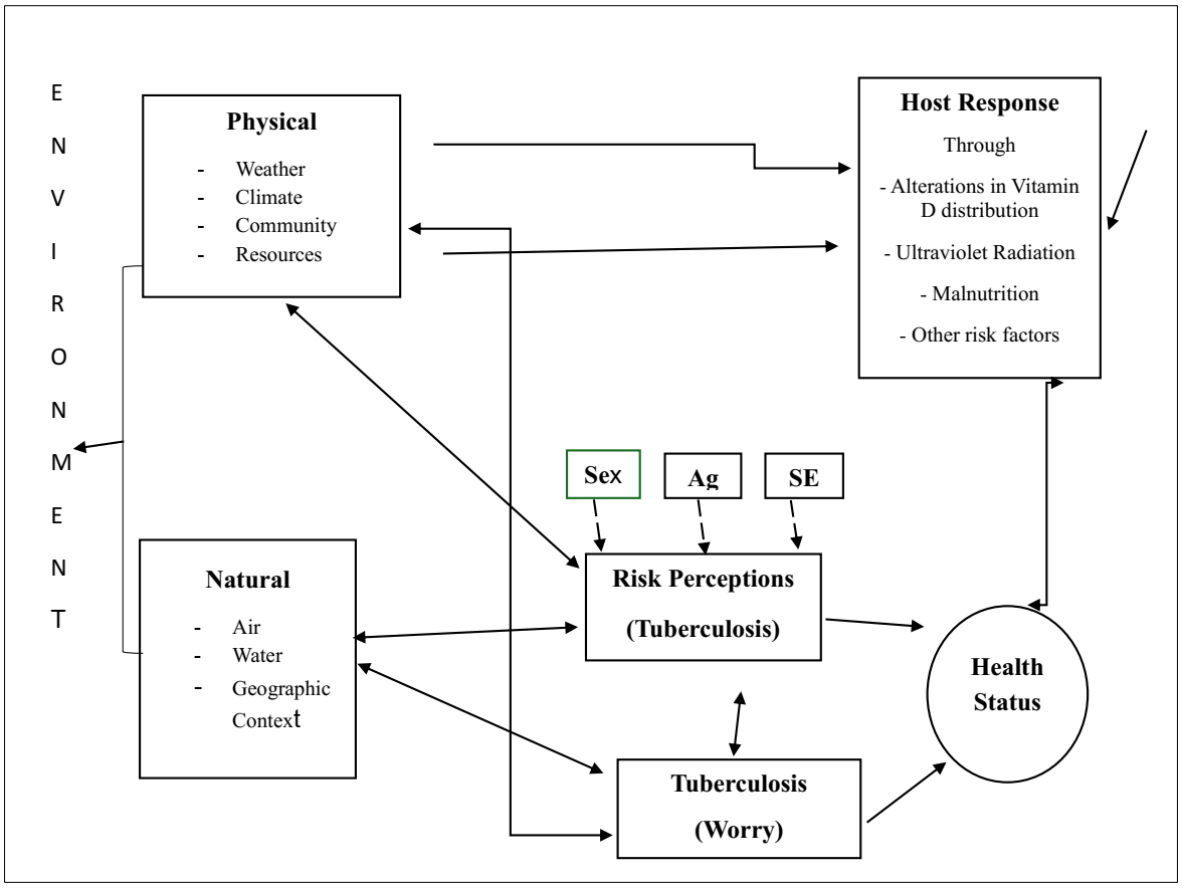

Figure 3: Conceptual Framework of Climate impacts on Tuberculosis through Diverse Pathways

The conceptual framework is illustrated in Figure 3, which shows a pathways relationship between the environment, tuberculosis (TB) risk time and social fabric are represented in the social environment; place vulnerability is an example of the built environment, the hazard potential functions through both the social and natural environment, while geographic context focuses on the natural aspects of the environment. Incorporating the Hazards-of- Place Model emphasizes the fact that a range of factors produce social vulnerability and thus cancer risk as vulnerability occurs within a spatial context.

The state or condition of an individual's environment influences their perceptions of risk for TB because disease does not occur in a vacuum, it occurs in the context of human circumstance. With that said, the environment and climate change was depicted as having a direct effect on TB risk perceptions -affects pathogen lifecycles and shift of breeding sites. Self-efficacy has been introduced as a factor that moderates the association between the environment and risk- reducing health behaviors. TB risk perceptions has been incorporated as a mediating factor between environment and risk-reducing health behaviors suggesting that engaging in health behaviors (e.g. TB screenings) are mediated by personal beliefs that one is at risk of developing disease. Gender, age, and socioeconomic status are incorporated in the conceptual framework as factors that confound TB risk perceptions. The conceptual model frames TB risk perceptions as a positive or negative influence on health-related self-efficacy (belief in one's ability to take care of their own health). The role of self-efficacy was not explored in this research paper.

CONCLUSIONS

Environmental factors and infectious diseases, especially tuberculosis, have a complicated and multidimensional interaction. The studies by Gelaw *et al*., (2022) and Uwishema *et al*., (2023) provide complementary insights into how temperature, altitude, and climate change may influence disease dynamics. Gelaw *et al*., (2022) offer a focused analysis of TB in relation to altitude and temperature, while Uwishema *et al*., (2023) present a broader examination of climate impacts on infectious diseases. The synthesis of these studies, along with additional literature, underscores the need for public health strategies that incorporate environmental factors. As climate change continues to shape global health landscapes, there is an urgent need for policies and interventions that address the complex interactions between climate, geography, and disease. Future research should continue to explore these relationships, as well as develop actionable insights for mitigating the public health impacts of climate-driven disease transmission.

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