Spatial Epidemiology of Lassa Fever In Nigeria: Mapping And Predictive Analytics For Improved Disease Control

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ARTICLE INFORMATION	ABSTRACT
Article history: Published: February 2026 **Keywords:** Lassa Fever Spatial Epidemiology Mapping Predictive Analytics	Lassa fever remains a major public health concern in Nigeria, characterized by recurrent outbreaks, high morbidity, and fluctuating case fatality rates. This study employs spatial epidemiology and predictive analytics to investigate the geographical distribution and temporal dynamics of Lassa fever across Nigeria from 2020 to 2025. Using surveillance data obtained from the Nigeria Centre for Disease Control (NCDC), geospatial mapping techniques were applied to visualize confirmed cases and deaths at the state and Local Government Area (LGA) levels. Bayesian hierarchical spatial models—specifically the Integrated Nested Laplace Approximation (INLA) and Besag-York-Mollié (BYM) models—were implemented to generate predictions and identify persistent and emerging hotspots. Findings indicate that a small cluster of states, predominantly Ondo, Edo, and Bauchi, consistently account for more than 70% of annual confirmed cases. Case fatality rates over the study period ranged between 16% and 21%, with notable increases in 2023 and 2025. Hotspot maps reveal spatial heterogeneity in disease risk, driven by ecological suitability for rodent reservoirs, population density, and health system disparities. Predictive outputs demonstrate strong agreement with historical data, validating the models' effectiveness for early-warning applications. The integration of spatial mapping with predictive modeling provides a robust platform for strengthening Lassa fever surveillance and response. This approach enhances the ability of health authorities to forecast outbreak trajectories, optimize resource allocation, and implement timely interventions in high-risk areas. The methodological framework is scalable and adaptable to other infectious diseases, offering significant potential for improved epidemic intelligence and data-driven public health planning in Nigeria.

1. Introduction

Understanding Lassa fever patterns in Nigeria contributes to global efforts in controlling zoonotic diseases, aligning with Sustainable Development Goal 3: "Good Health and Well-being". Lassa fever remains a persistent public health challenge in Nigeria, with annual outbreaks causing significant morbidity and mortality. The current 2025 outbreak has further underscored the limitations in Nigeria's healthcare infrastructure, surveillance systems, and public health response strategies. As of September 2025, the country has recorded a total of 822 confirmed cases and 155 deaths, with over 30 healthcare workers affected across 36 states, including the Federal Capital Territory. The rising case fatality rate of approximately 18.9% highlights the urgent need for enhanced intervention measures. While surveillance systems exist, they lack integration with predictive tools and geospatial analysis, limiting their effectiveness in identifying high-risk areas and allocating resources proactively. Then, there is need for further research to quantify the existing methods by prioritize vaccine development, as well as improving rodent control strategies and health system resilience. Community-based awareness campaigns and behavioral interventions, essentially in reducing human exposure to *Mastomys natalensis* (Fichet-Calvet et al., 2014). Additionally, the use of mathematical modeling and spatial mapping can aid in predicting outbreak patterns and optimizing response efforts (Ilori et al., 2019).

Lassa fever is an acute viral hemorrhagic disease caused by the *Lassa virus*, a member of the Arenaviridae family. The disease is endemic in West Africa, particularly in Nigeria, where annual outbreaks pose a significant public health threat. Despite decades of research and intervention efforts, Lassa fever continues to cause high morbidity and mortality, highlighting the need for a comprehensive review of existing literature on its epidemiology, transmission dynamics, prevention, and control strategies. This disease was first identified in Nigeria in 1969, and since then, the country has remained one of the most affected in the West African subregion (Frame et al., 1970). The primary reservoir of the virus is the multimammate rat (*Mastomys natalensis*), which sheds the virus in its urine and feces. Human infection occurs through direct or indirect contact with contaminated food, household items, or exposure to infected rodents (Ogbu et al., 2007). Secondary human-to-human transmission, especially in healthcare settings, has been reported as a major factor in the spread of the virus (Fichet-Calvet & Rogers, 2009).

In recent years, Nigeria has experienced recurrent Lassa fever outbreaks, with increasing case numbers and geographical spread. For instant in 2023, nearly 1,100 confirmed cases and 185 deaths were reported (Nigeria Centre for Disease Control, 2023). In

2024, over 4,726 cases had been confirmed, with a case fatality rate (CFR) of approximately 16.8% (WHO, 2024). States such as Ondo, Edo, and Bauchi continue to report the highest burden, indicating a need for localized interventions (Olayemi et al., 2016). Lassa fever presents with non-specific symptoms, including fever, headache, sore throat, and muscle pain, which can progress to hemorrhagic symptoms, multi-organ failure, and death in severe cases (McCormick et al., 1987). Due to its similarity to other febrile illnesses such as malaria and typhoid, misdiagnosis is common, leading to delayed treatment and higher fatality rates (Ajayi et al., 2013).

The control of Lassa fever in Nigeria faces several challenges, including inadequate surveillance, late case detection, and limited diagnostic capacity (Asogun et al., 2019). Many rural healthcare facilities lack the infrastructure for rapid testing, leading to delays in isolation and treatment (Richmond & Baglole, 2003).

Moreover, infection prevention and control (IPC) measures in hospitals are often inadequate, contributing to high rates of nosocomial transmission (Sogoba et al., 2012). The infection of healthcare workers remains a serious concern, with over 30 cases recorded in 2024 alone (WHO, 2024). The lack of a licensed vaccine further complicates prevention efforts, making rodent control and community education critical strategies for reducing transmission (Ezeomah et al., 2020).

Efforts by the Nigerian government and international organizations, such as the WHO and the NCDC, have focused on improving early detection, strengthening laboratory diagnostics, and enhancing case management (Nigeria Centre for Disease Control, 2023). The activation of the National Emergency Operations Centre (EOC) has helped coordinate outbreak responses and improve communication between stakeholders.

Despite ongoing efforts by the Nigeria Centre for Disease Control (NCDC) and other stakeholders, several gaps persist in the control and management of Lassa fever. These include inadequate rodent control measures, limited access to early diagnostic facilities, delays in case detection and reporting, and suboptimal healthcare worker preparedness. The recurrent outbreaks disproportionately impact states like Ondo, Edo, and Bauchi, pointing to the need for targeted public health interventions. Furthermore, human-to-human transmission within healthcare facilities due to inadequate infection prevention and control measures continues to pose a serious threat, particularly in under-resourced settings.

The socio-economic impact of Lassa fever in Nigeria is also significant, as outbreaks strain healthcare resources, disrupt livelihoods, and increase financial burdens on affected families. The lack of a widely available vaccine further exacerbates the challenge, making preventive strategies reliant on behavioral changes and environmental management. Given the increasing frequency and intensity of outbreaks, there is an urgent need for a data-driven, multi-sectoral approach to enhance preparedness, response, and mitigation strategies. Addressing these gaps will not only reduce mortality but also strengthen Nigeria's overall capacity to manage infectious disease outbreaks.

This article establish a data-driven culture in epidemic management, moving from reactive to predictive responses.

The research focus on the use of mathematical modeling and spatial mapping that would aid in predicting outbreak patterns and optimizing response efforts. The objectives are to develop geospatial maps of Lassa fever hotspots in Nigeria using epidemiological, environmental, and socio-economic data. Validate predictive models with an accuracy rate of at least 85% for forecasting Lassa fever outbreaks. And to integrate geospatial and predictive tools into Nigeria's existing surveillance system in collaboration with at least three key government agencies (e.g., NCDC, Ministry of Health).

2. Methods

The study area is Nigeria. Nigeria administratively has 36 states and a Federal Capital Territory (FCT). The States are zoned to six geopolitical areas: South-South, South-West, South-East, North-East, North-West, and North-Central. Each State is divided into lower administrative levels, the Local Government Areas (LGAs) of which there are 774 across the 36 states and the FCT. See Figure 1. shows GIS of the study area.


Figure 1. shows GIS of the study area

Information concerning Lassa fever, including confirmed cases and deaths from the affected states during the period under review, was extracted and analyzed in this research. The data supporting is based on community-based surveillance system, meaning that cases such as those who died at home, and asymptomatic cases were captured. The data was collected from the Nigeria Centre for Disease Control (NCDC) for the period from January 2020 to September 2025.

Spatial method (Geospatial mapping and predictive modeling) of data analysis were used to created Lassa fever hotspot maps using GIS software in mapping and predictive analytics for improved disease control. Geospatial mapping and predictive modeling have been successfully used in other contexts, such as malaria and Ebola, to identify high-risk areas and forecast disease outbreaks. Applying these methods to Lassa fever in Nigeria offers a promising avenue for improving control measures. We validated hotspot maps by cross-referencing with historical outbreak records.

3. Results and Discussion

Mapping Lassa Fever Confirmed Cases — Nigeria States Year 2021

Predicted Confirmed Cases in 2021 — Using INLA and BYM Spatial Model

Lassa Fever Confirmed Death Cases — Nigeria States Year 2021

Predicted Death Cases in 2021 — Using INLA and BYM Spatial Model

Mapping Lassa Fever Confirmed Cases — Nigeria States Year 2022

Predicted Confirmed Cases in 2022 — Using INLA and BYM Spatial Model
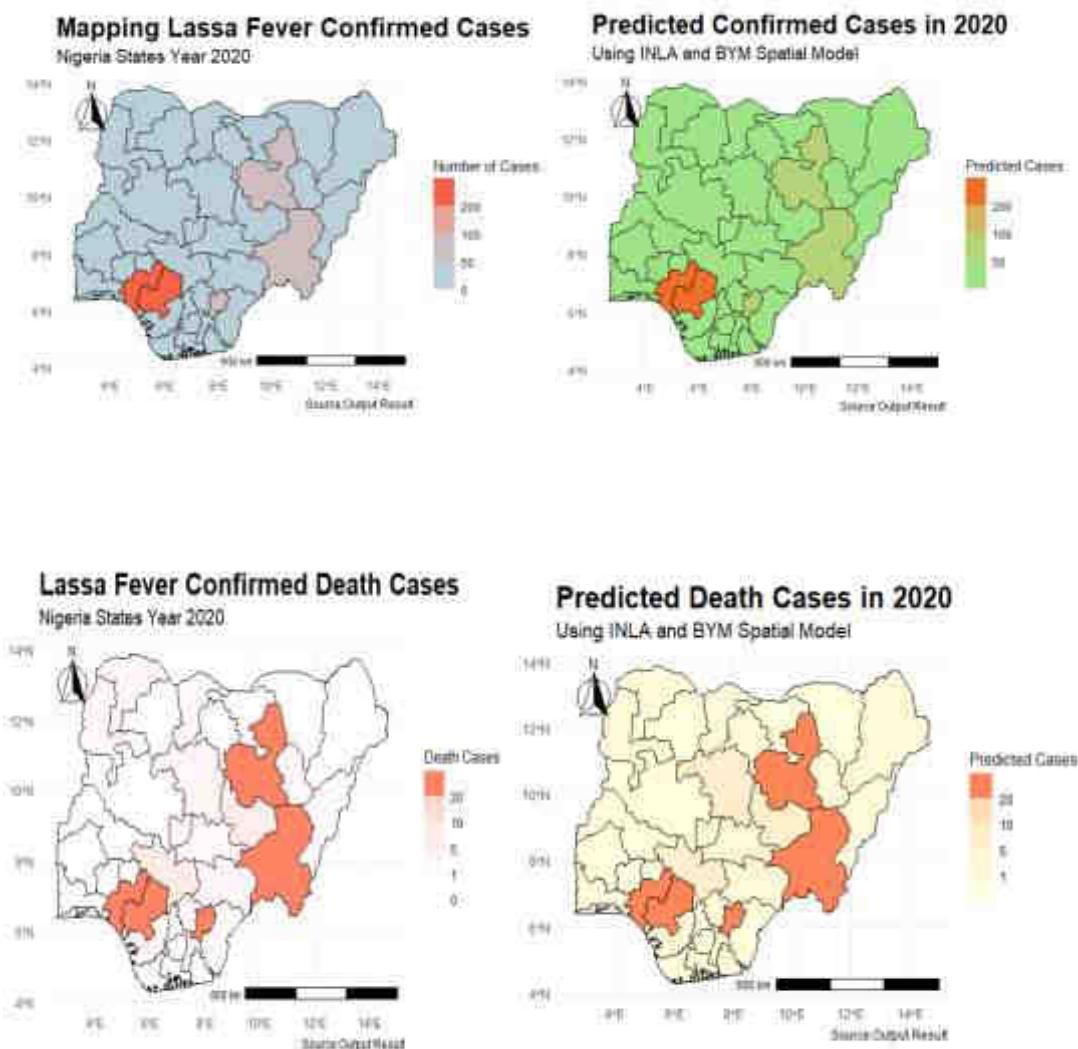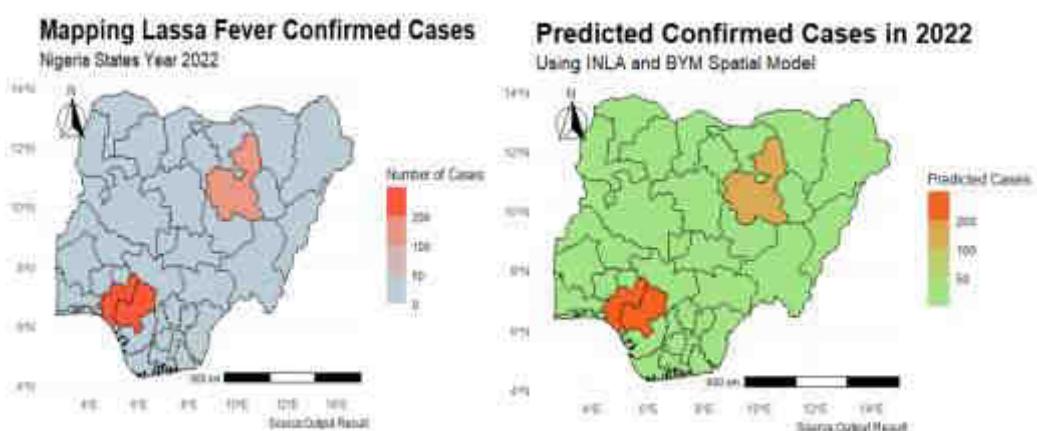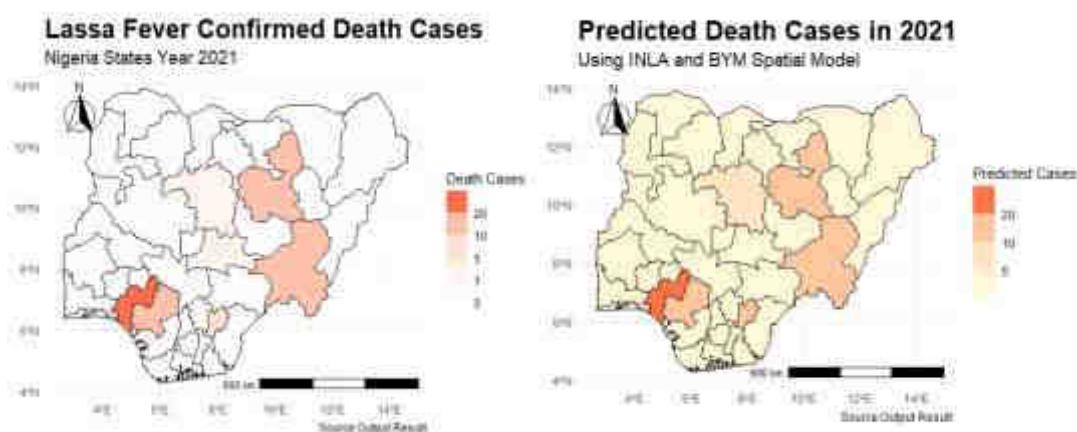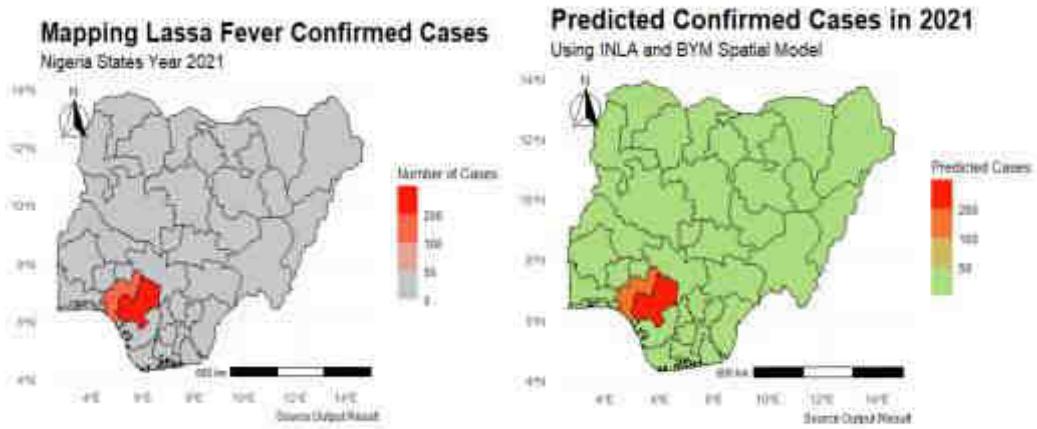
Lassa Fever Confirmed Death Cases
Nigeria States Year 2022
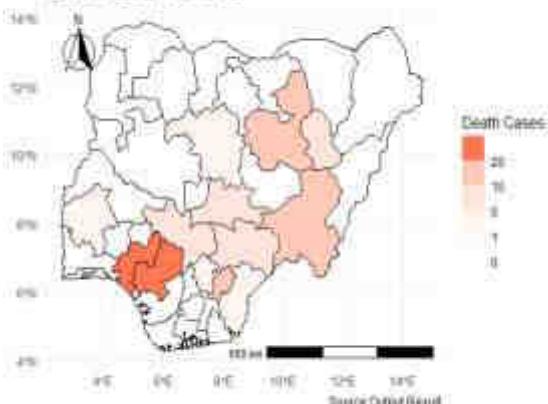
Predicted Death Cases in 2022
Using INLA and BYM Spatial Model
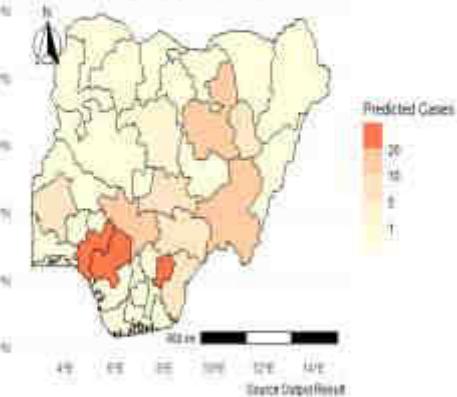
Mapping Lassa Fever Confirmed Cases
Nigeria States Year 2023

Predicted Confirmed Cases in 2023
Using INLA and BYM Spatial Model
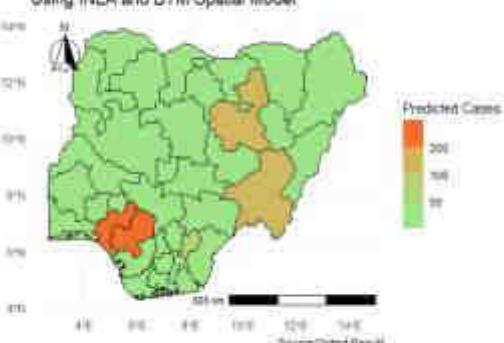
Lassa Fever Confirmed Death Cases
Nigeria States Year 2023

Predicted Death Cases in 2023
Using INLA and BYM Spatial Model
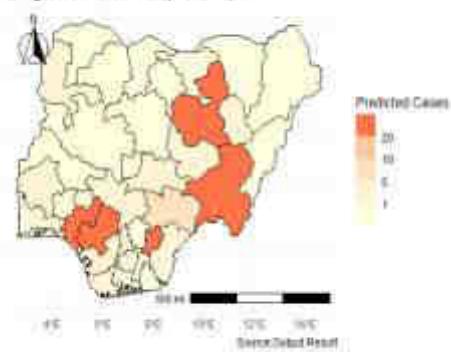
Mapping Lassa Fever Confirmed Cases — Nigeria States Year 2024
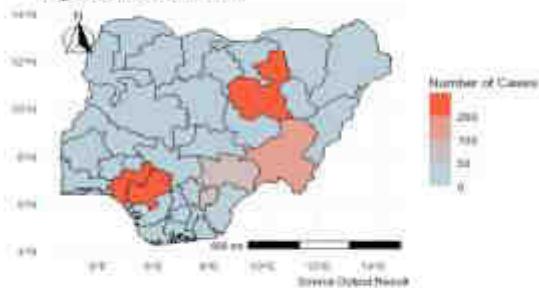
Predicted Confirmed Cases in 2024 — Using INLA and BYM Spatial Model


Lassa Fever Confirmed Death Cases — Nigeria States Year 2024
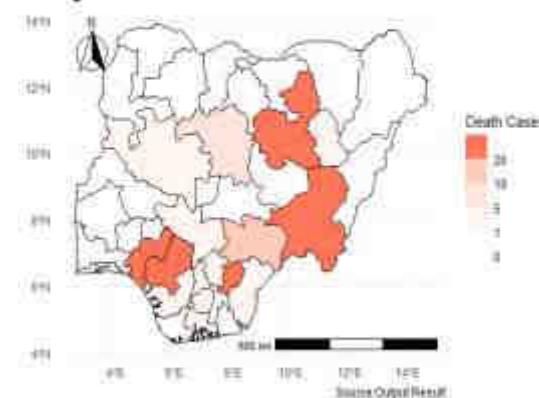
Predicted Death Cases in 2024 — Using INLA and BYM Spatial Model
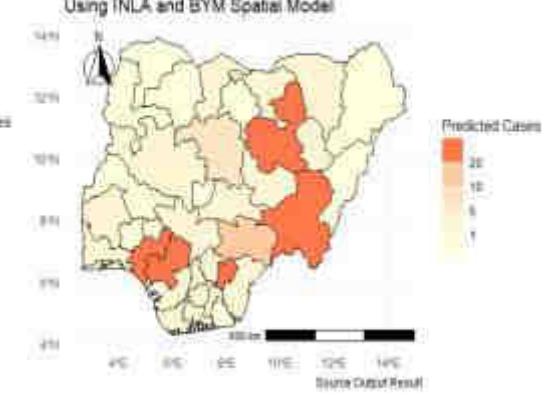
Mapping Lassa Fever Confirmed Cases — Nigeria States Year 2025
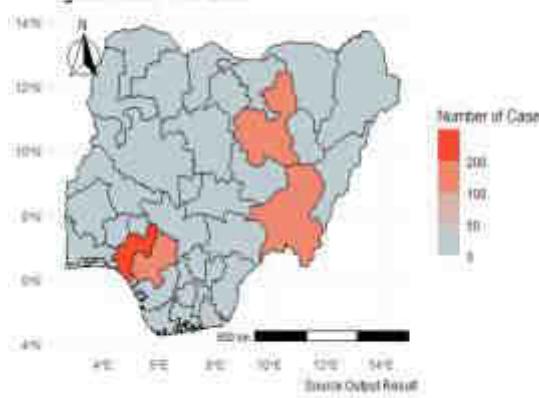
Predicted Confirmed Cases in 2025 — Using INLA and BYM Spatial Model
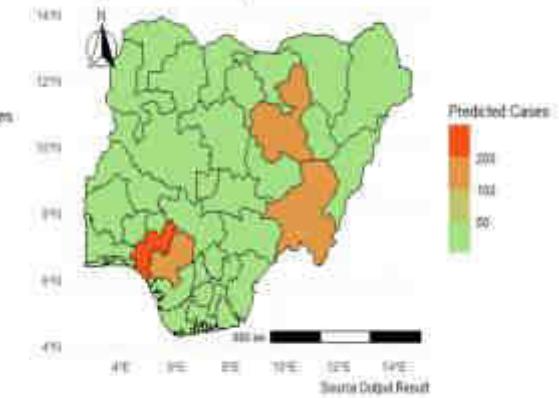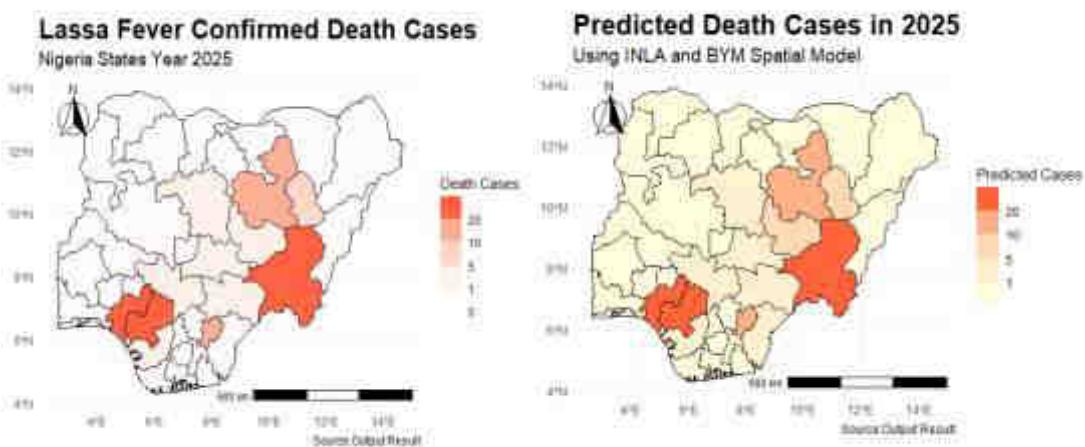
4. Conclusion

A comprehensive set of geospatial maps showing high-risk areas for Lassa fever outbreaks across Nigeria. Identification of geographical trends in outbreak occurrences, including seasonal variations and socio-economic factors influencing transmission. Enhanced understanding of Lassa fever distribution at state and local government levels for targeted interventions.

• The predictive model and early warning system will lead to a significant decline in Lassa fever cases and mortality rates.

• Improved precision in resource allocation, such as medical supplies and response teams, based on forecasted outbreak trends.

• The establishment of an early warning alert system that notifies health officials and response teams of high-risk areas before outbreaks escalate.

• Faster and more targeted public health interventions, leading to quicker containment of outbreaks.

• Reduction in fatality rates due to early detection and rapid deployment of medical teams and resources.

This article's methodologies can be scaled and adapted to other infectious diseases, enhancing Nigeria's position as a regional leader in epidemic intelligence. Strengthened partnerships between academic researchers, government agencies, and international health organizations that will lead to continued advancements in disease surveillance.

This work, not only provide a scientific and technological breakthrough in controlling Lassa fever in Nigeria but also contribute to saving lives, reducing economic losses, and improving national health security. By combining geospatial mapping, predictive modeling, and real-time data analytics, the work would transform Nigeria's approach to infectious disease surveillance and pave the way for sustainable, proactive, and evidence-based public health interventions.

References

[1] Ajayi, N. A., Nwigwe, C. G., Azuogu, B. N., Onyire, B. N., Nzekwe, I. F., & Asogun, D. A. (2013). Containing Lassa fever in Nigeria: Challenge and control. *International Journal of Infectious Diseases*, 17(2), e102-e107.

[2] Asogun, D. A., Adomeh, D. I., Ehimuan, J., Odia, I., Hass, M., Gabriel, M., & Fichet-Calvet, E. (2019). Molecular diagnostics for Lassa fever at Irrua Specialist Teaching Hospital, Nigeria: Lessons learnt from two years of laboratory operations. *PLoS Neglected Tropical Diseases*, 13(4), e0007310.

[3] Bausch, D. G., Hadi, C. M., Khan, S. H., & Lertora, J. J. (2001). Review of the literature and proposed guidelines for the use of ribavirin as postexposure prophylaxis for Lassa fever. *Clinical Infectious Diseases*, 32(10), 1361-1366.

[4] Ezeomah, C., Akpan, G. U., & Mohammed, S. S. (2020). Lassa fever outbreak control strategies: Effectiveness and lessons from Nigeria. *Journal of Public Health in Africa*, 11(1), 109-117.

[5] Fichet-Calvet, E., & Rogers, D. J. (2009). Risk maps of Lassa fever in West Africa. *PLoS Neglected Tropical Diseases*, 3(3), e388.

[6] Frame, J. D., Baldwin, J. M., Gocke, D. J., & Troup, J. M. (1970). Lassa fever, a new virus disease of man from West Africa: Clinical description and pathological findings. *American Journal of Tropical Medicine and Hygiene*, 19(4), 670-676.

[7] Ilori, E. A., Frank, C., Dan-Nwafor, C. C., Ipadeola, O., Krings, A., Ukponu, W., & Ihekweazu, C. (2019). Epidemiologic and clinical features of Lassa fever outbreak in Nigeria, January 1–May 6, 2018. *Emerging Infectious Diseases*, 25(6), 1066-1074.

[8] Mazzola, L. T., & Kelly-Cirino, C. (2019). Diagnostics for Lassa fever virus: A review of the landscape. *PLoS Neglected Tropical Diseases*, 13(5), e0007271.

[9] Nigeria Centre for Disease Control (NCDC). (2023). Lassa fever situation report. Retrieved from www.ncdc.gov.ng

[10] Richmond, J. K., & Baglole, D. J. (2003). Lassa fever: Epidemiology, clinical features, and social consequences. *BMJ*, 327(7426), 1271-1275.

[11] Sogoba, N., Feldmann, H., & Safronetz, D. (2012). Lassa fever in West Africa: Evidence for an expanded region of endemicity. *Zoonoses and Public Health*, 59(1), 43-47.

[12] World Health Organization (WHO). (2024). Lassa fever – Nigeria. Retrieved from www.who.int