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Spatial Epidemiology of Lassa Fever in Nigeria: Mapping and Predictive Analytics for Improved Disease Control

Aliu Abbas Hassan & Aliu Tawakalitu Olaitan
Federal Polytechnic Ile-Oluji, Nigeria; Rufus Giwa Polytechnic Owo, Nigeria
abbaliu@fedpolel.edu.ng

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Abstract

Lassa fever remains a major public health concern in Nigeria because of its recurrent outbreaks, high morbidity, and fluctuating case fatality rates. This study investigates the geographical distribution and temporal dynamics of Lassa fever in Nigeria from 2020 to 2025 using spatial epidemiology and predictive analytics. Surveillance data obtained from the Nigeria Centre for Disease Control were analyzed through geospatial mapping to visualize confirmed cases and deaths at the state and Local Government Area levels, while Bayesian hierarchical spatial models, specifically the Integrated Nested Laplace Approximation and Besag-York-Mollié models, were applied to generate predictions and identify persistent and emerging hotspots. The findings show that a small cluster of states, particularly Ondo, Edo, and Bauchi, consistently accounted for more than 70% of annual confirmed cases. Case fatality rates ranged from 16% to 21% during the study period, with notable increases in 2023 and 2025. The hotspot maps further reveal marked spatial heterogeneity in disease risk, shaped by ecological suitability for rodent reservoirs, population density, and disparities in health systems. In addition, the predictive outputs show strong agreement with historical data, confirming the usefulness of the models for early warning. The study concludes that integrating spatial mapping with predictive modeling provides a robust framework for strengthening Lassa fever surveillance and response in Nigeria. These findings contribute a scalable and adaptable methodological approach that can support outbreak forecasting, resource optimization, timely intervention in high-risk areas, and broader data-driven epidemic intelligence for infectious disease control.

Keywords: Lassa Fever; Spatial Epidemiology; Predictive Analytics; Bayesian Hierarchical Models; Nigeria

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).

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

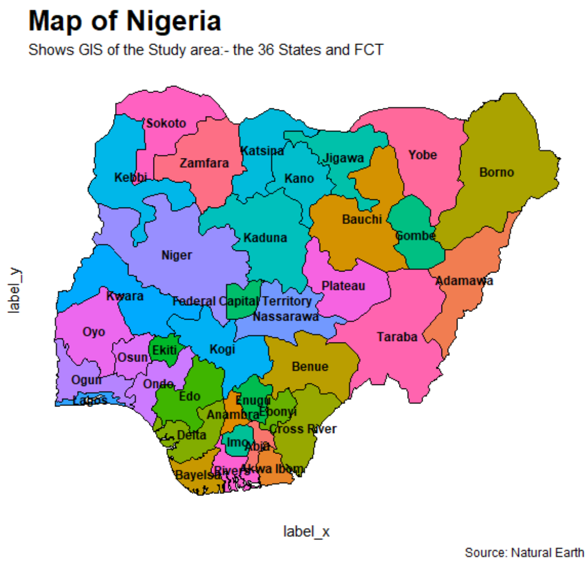
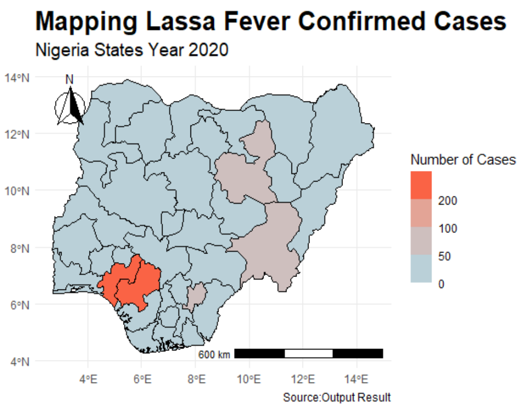


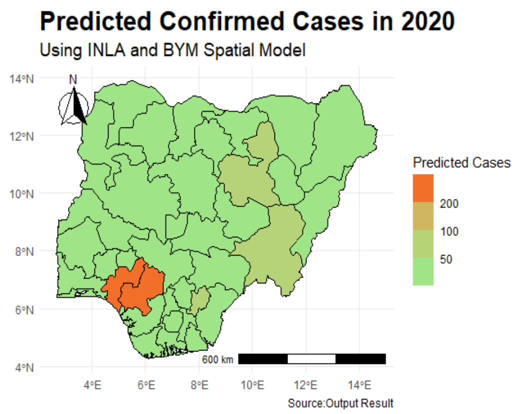
Figure 1. shows GIS of the study area

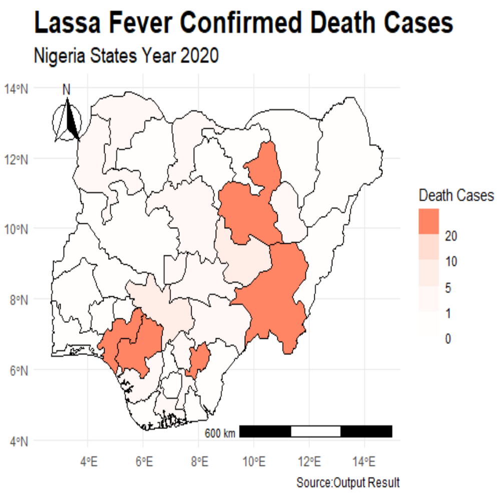
Information concerning Lassa fever, including confirmed cases and deaths from the affected states during the period under review, was extracted and analyzed in this research. The data supporting is based on community-based surveillance system, meaning that cases such as those who died at home, and asymptomatic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

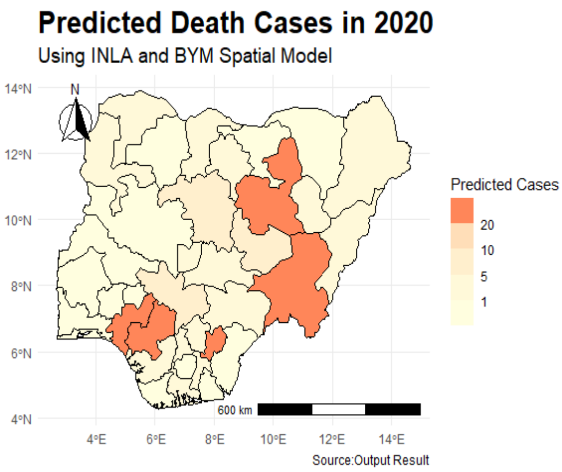
Spatial method (Geospatial mapping and predictive modeling) of data analysis were used to created Lassa fever hotspot maps using GIS software in mapping and predictive analytics for improved disease control. Geospatial mapping and predictive modeling have been successfully used in other contexts, such 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.

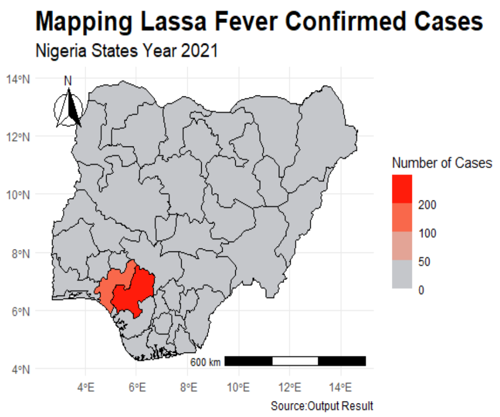
Results and Discussion










Mapping Lassa Fever Confirmed Cases
Nigeria States Year 2021
N
14°N
12°N
10°N
8°N
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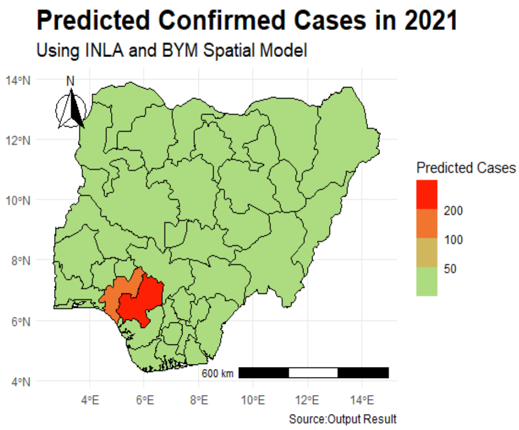
4°E 6°E 8°E 10°E 12°E 14°E
600 km
Number of Cases
200
100
50
0
Source:Output Result


Predicted Confirmed Cases in 2021
Using INLA and BYM Spatial Model
N
14°N
12°N
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600 km
Predicted Cases
200
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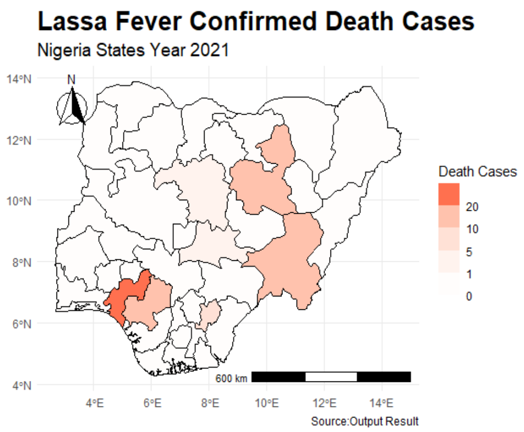
Source:Output Result


Lassa Fever Confirmed Death Cases
Nigeria States Year 2021
N
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10°N
8°N
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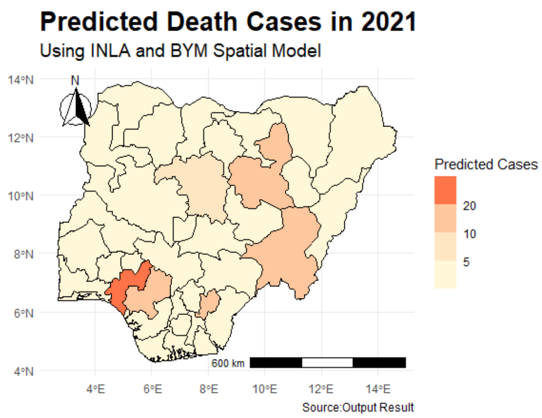
600 km
Death Cases
20
10
5
1
0
Source:Output Result


Predicted Death Cases in 2021
Using INLA and BYM Spatial Model
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600 km
Predicted Cases
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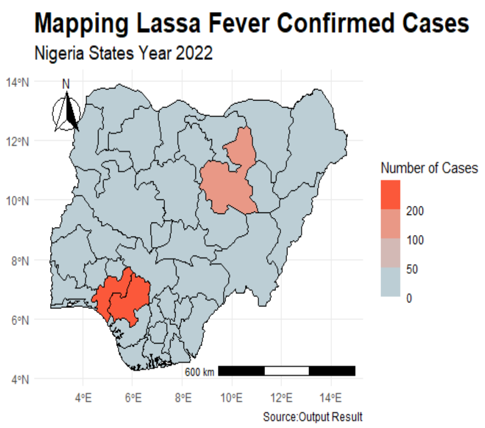
Source:Output Result


Mapping Lassa Fever Confirmed Cases
Nigeria States Year 2022
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600 km
Number of Cases
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100
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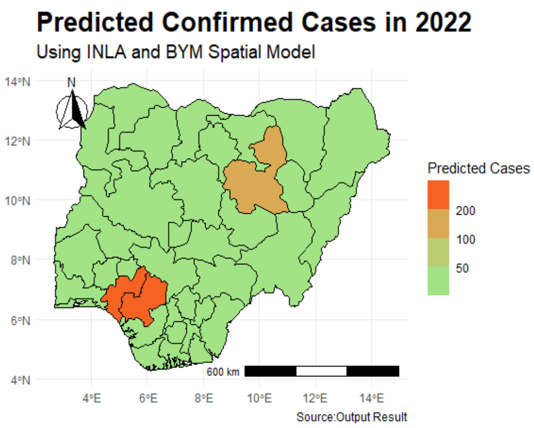
0
Source:Output Result


Predicted Confirmed Cases in 2022
Using INLA and BYM Spatial Model
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Predicted Cases
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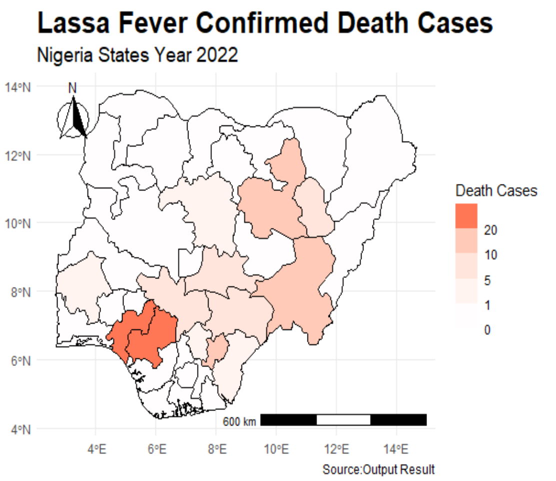
Source:Output Result


Lassa Fever Confirmed Death Cases
Nigeria States Year 2022
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600 km
Death Cases
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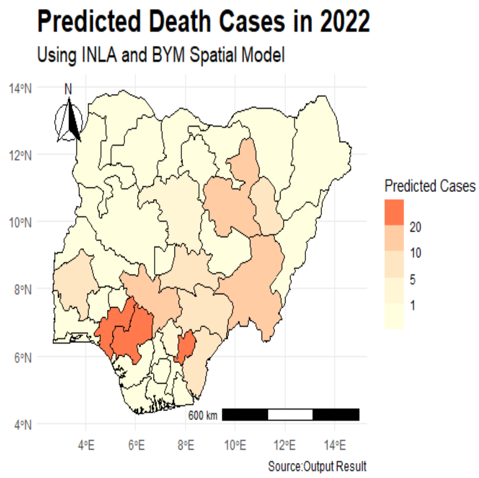
Source:Output Result


Predicted Death Cases in 2022
Using INLA and BYM Spatial Model
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600 km
Predicted Cases
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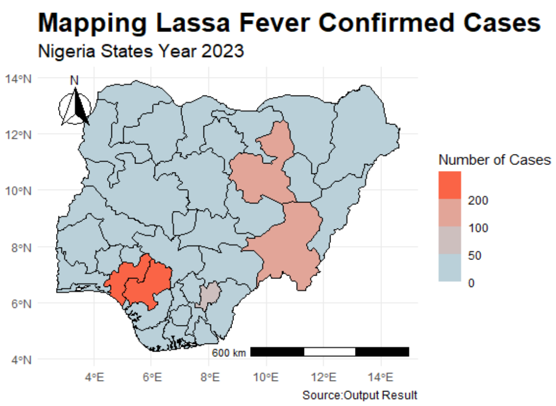
1
Source:Output Result


Mapping Lassa Fever Confirmed Cases
Nigeria States Year 2023
N
14°N
12°N
10°N
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8°E
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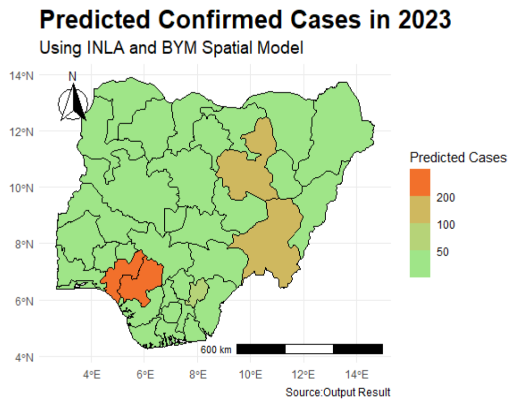
12°E
14°E
600 km
Number of Cases
200
100
50
0
Source:Output Result


Predicted Confirmed Cases in 2023
Using INLA and BYM Spatial Model
N
14°N
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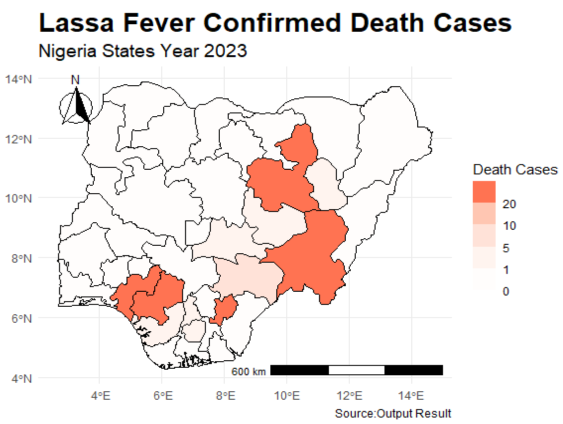
12°E
14°E
600 km
Predicted Cases
200
100
50
Source:Output Result


Lassa Fever Confirmed Death Cases
Nigeria States Year 2023
N
14°N
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10°N
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600 km
Death Cases
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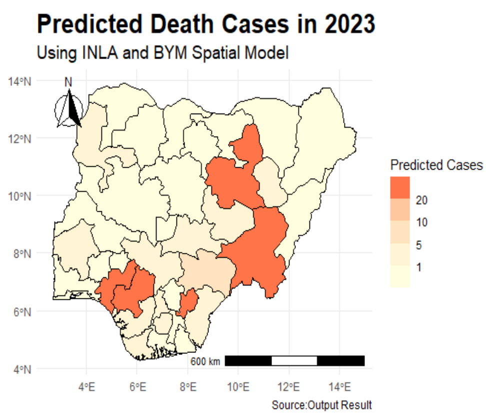
1
0
Source:Output Result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Using INLA and BYM Spatial Model
N
14°N
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Predicted Cases
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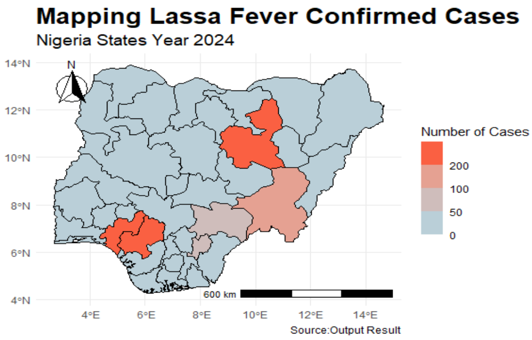
10
5
1
Source:Output Result


Mapping Lassa Fever Confirmed Cases
Nigeria States Year 2024
N
Number of Cases
200
100
50
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600 km
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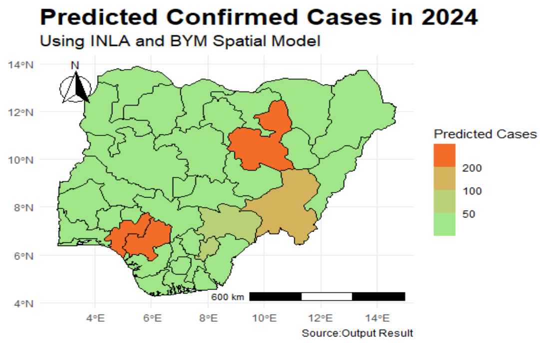
12°E
14°E
Source:Output Result


Predicted Confirmed Cases in 2024
Using INLA and BYM Spatial Model
N
Predicted Cases
200
100
50
600 km
14°N
12°N
10°N
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4°N
4°E
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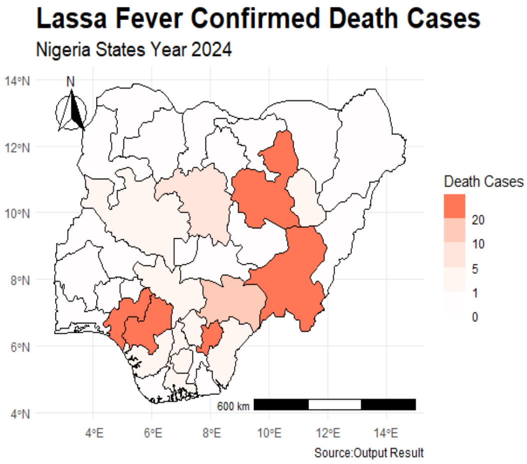
14°E
Source:Output Result


Lassa Fever Confirmed Death Cases
Nigeria States Year 2024
N
Death Cases
20
10
5
1
0
600 km
14°N
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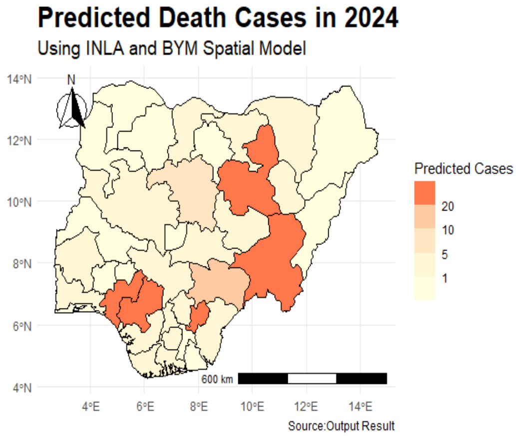
14°E
Source:Output Result


Predicted Death Cases in 2024
Using INLA and BYM Spatial Model
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Predicted Cases
20
10
5
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600 km
14°N
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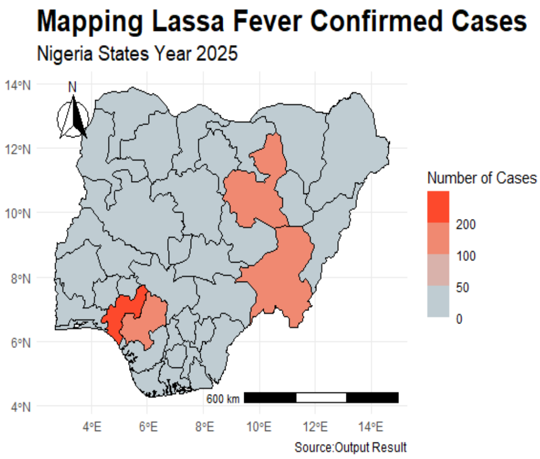
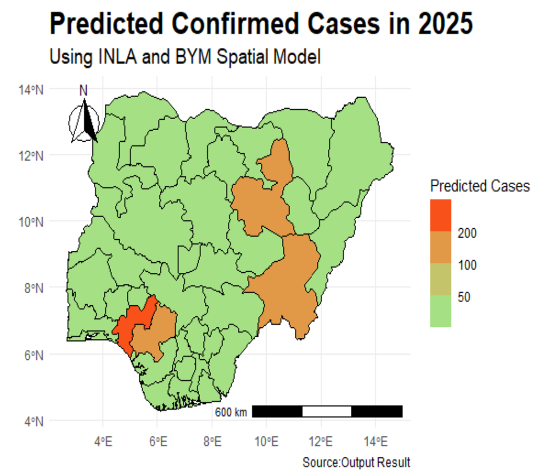
14°E
Source:Output Result


Mapping Lassa Fever Confirmed Cases
Nigeria States Year 2025
N
Number of Cases
200
100
50
0
600 km
14°N
12°N
10°N
8°N
6°N
4°N
4°E
6°E
8°E
10°E
12°E
14°E
Source:Output Result


Predicted Confirmed Cases in 2025
Using INLA and BYM Spatial Model
N
Predicted Cases
200
100
50
600 km
14°N
12°N
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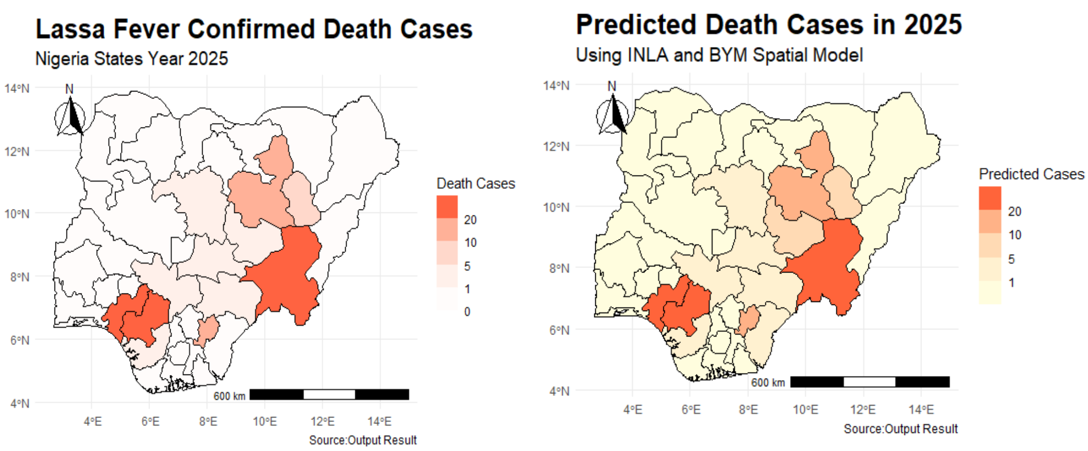
Source:Output Result



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.

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