International Journal of Agriculture, Environment and Bioresearch

Vol. 11, No. 06; 2026

ISSN: 2456-8643

ARTIFICIAL INTELLIGENCE FOR PUBLIC HEALTH SURVEILLANCE: EMERGING APPLICATIONS IN NIGERIA AND AFRICA

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https://doi.org/10.35410/IJAEB.2026.1086

Received: 1 Oct 2026/Published: 10 Nov 2026

ABSTRACT

Artificial intelligence (AI) is increasingly being embedded into infectious disease surveillance systems across sub-Saharan Africa, offering opportunities to close long-standing gaps in early outbreak detection, data analytics, and resource allocation. This review synthesises emerging evidence on AI-enabled public health surveillance in Nigeria and the wider African continent, drawing on peer-reviewed literature published between 2020 and 2025. The review examines three domains of application: (i) digital surveillance and early-warning platforms such as the Surveillance Outbreak Response Management and Analysis System (SORMAS), the District Health Information Software 2 (DHIS2), and natural language processing (NLP)-based epidemic intelligence tools; (ii) machine learning-based predictive analytics for malaria, tuberculosis, cholera, monkeypox, and coronavirus disease 2019 (COVID-19); and (iii) AI-assisted case-finding and treatment-adherence monitoring. Persistent barriers to scale-up include fragmented digital infrastructure, unreliable electricity and internet connectivity, scarcity of local data-science expertise, poor data quality and interoperability, and unresolved ethical, governance, and algorithmic-bias concerns. Opportunities identified include cross-sectoral data-sharing frameworks, investment in local AI talent, context-specific model validation, and regional coordination led by the Africa Centres for Disease Control and Prevention (Africa CDC) and the Nigeria Centre for Disease Control and Prevention (NCDC). The review concludes that AI holds transformative potential for African public health surveillance, provided infrastructural, ethical, and capacity-building gaps are deliberately addressed through coordinated policy action.

Keywords: Artificial intelligence; public health surveillance; disease outbreak; machine learning; Nigeria; Africa; digital health.

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ISSN: 2456-8643

1. INTRODUCTION

Infectious disease outbreaks remain a leading cause of morbidity and mortality across sub-Saharan Africa, with the continent recording more than 160 public health emergencies annually, most of which are infectious in origin [1]. Nigeria, as Africa's most populous nation, bears a disproportionate share of this burden, having experienced successive outbreaks of Ebola virus disease, monkeypox, Lassa fever, cholera, measles, and coronavirus disease 2019 (COVID-19) within the past decade [2]. Conventional, paper-based surveillance approaches have repeatedly proven too slow and fragmented to support timely outbreak detection, case management, and resource deployment, particularly in low-resource and rural settings [3].

Artificial intelligence (AI), encompassing machine learning (ML), deep learning, and natural language processing (NLP), has emerged as a promising complement to traditional surveillance, offering the capacity to analyse heterogeneous epidemiological, genomic, climatic, and behavioural data streams at a scale and speed unattainable through manual methods [4]. Interest in AI for African healthcare delivery more broadly has grown steadily over the past five years [5], and adoption of AI-enabled tools within public health has accelerated markedly since the COVID-19 pandemic exposed critical weaknesses in digital health infrastructure and catalysed government and donor investment in digital disease-surveillance platforms [6].

In Nigeria specifically, the NCDC has progressively digitised its Integrated Disease Surveillance and Response (IDSR) system through tools such as SORMAS and DHIS2, both of which now incorporate elements of automated analytics and dashboard-based decision support [7]. Beyond these platform-level innovations, a growing body of Nigerian and African research has applied supervised machine learning, Bayesian inference, and deep learning models to predict COVID-19 case trajectories, malaria transmission, and tuberculosis hotspots [8].

Despite this progress, the translation of AI research into routine, sustainable public health practice in Nigeria and across Africa remains constrained by infrastructural, data, workforce, and governance challenges [9]. This review therefore aims to (i) synthesise emerging applications of AI in public health surveillance across Nigeria and Africa; (ii) critically examine the barriers limiting large-scale adoption; and (iii) identify opportunities and policy directions for strengthening AI-enabled surveillance systems on the continent.

2. METHODOLOGY

This is a narrative review informed by a structured search of peer-reviewed literature indexed in PubMed/MEDLINE, Scopus, Web of Science, and reputable open-access repositories (PubMed Central, arXiv, and publisher platforms including Springer, Elsevier ScienceDirect, MDPI, BioMed Central, Frontiers, and Wiley). Search terms combined "artificial intelligence", "machine learning", "deep learning", "public health surveillance", "disease outbreak", "Nigeria", and "Africa". Articles published between January 2020 and 2025, written in English, and reporting original research, scoping/systematic reviews, or authoritative commentaries on AI applications in African public health surveillance were prioritised for inclusion. Reference lists of key papers were hand-searched to identify additional relevant sources. Non-peer-reviewed sources and material without verifiable digital object identifiers (DOIs) were excluded from the final reference list.

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AI Applications in Public Health Surveillance

Digital Surveillance and Early-Warning Platforms

SORMAS, an open-source mobile health (mHealth) platform originally developed during the 2014–2015 West African Ebola outbreak, has become the primary electronic backbone of Nigeria's outbreak response, supporting case notification, contact tracing, and epidemiological analysis across more than a dozen priority diseases [7]. Its deployment during the 2017–2019 monkeypox outbreak in Nigeria demonstrated substantially improved timeliness and completeness of case reporting compared with the conventional paper-based system [7]. A retrospective epidemiological analysis of the same outbreak further highlighted how urbanisation and waning smallpox-vaccine-derived immunity interact with surveillance gaps to drive disease re-emergence, underscoring the value of continuous digital monitoring [10].

Complementing SORMAS, DHIS2 underpins Nigeria's routine immunisation data module, and its implementation between 2014 and 2019 was associated with measurable improvements in the timeliness and completeness of routine immunisation reporting and dashboard-based decision-making [11]. Regional comparative work across East Africa has similarly documented the value of mobile-based, open-source outbreak-management systems in strengthening case detection where laboratory and administrative capacity is limited [12,13]. More recently, NLP-driven epidemic intelligence tools that scan open-source media, social platforms, and grey literature for early outbreak signals have begun to be adapted for the Nigerian context, including integration of Nigerian Pidgin English search terms, which produced a marked increase in detected outbreak reports, reflecting a broader continental shift toward automated, non-traditional surveillance sources [14].

Predictive Analytics for Infectious Disease Forecasting

Machine learning has been widely applied to COVID-19 case forecasting in Nigeria. Comparative modelling using regression, autoregressive integrated moving average (ARIMA), and machine learning algorithms found that ensemble tree-based models outperformed classical statistical approaches in forecasting new COVID-19 cases nationally [8]. A complementary negative-binomial regression approach was similarly used to generate short-term infection forecasts to support pandemic decision-making during the early phase of the outbreak [15].

In malaria surveillance, several Nigerian studies have applied supervised machine learning to sociodemographic, environmental, and clinical data to predict Plasmodium falciparum antigen positivity, achieving improved discrimination beyond conventional parasitological testing alone [16]. Deep learning-based clinical assessment algorithms have also been validated to improve triage accuracy for malaria among Nigerian children relative to standard Integrated Management of Childhood Illness protocols [17]. Symptom-based machine learning classifiers have further been proposed as low-cost, rapid diagnostic-support tools suited to resource-constrained primary care settings [18].

For tuberculosis (TB), a Bayesian inference model trained on community-level active case-finding data and open-source contextual covariates was used to generate a customised geoportal identifying high-TB-risk population clusters across four south-western Nigerian states; predicted hotspots yielded significantly higher TB positivity than conventionally selected sites [19]. In the wider region, deep learning frameworks (three-dimensional residual networks) applied to self-recorded medication-intake videos have shown strong discriminatory performance for

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ISSN: 2456-8643

monitoring TB treatment adherence, illustrating the potential of computer-vision-based digital adherence technologies for resource-limited settings [20].

Telemedicine and Health-System Support

Beyond outbreak-specific applications, AI-enabled telemedicine has expanded incrementally in Nigeria, particularly following the disruption of in-person care during the COVID-19 pandemic, although uptake remains constrained relative to high-income comparators [21]. Complementary digital-health strategies, including AI-supported triage and remote consultation tools, have also been proposed as mechanisms to mitigate the effects of health-workforce migration ("brain drain") on service delivery across the continent [22]. Table 1 presents the selected AI/machine learning applications in public health surveillance in Nigeria and Africa (2020–2025), while Figure 1 gives the Conceptual framework of an AI-enabled public health surveillance pipeline in Nigeria.

Table 1. Selected AI/machine learning applications in public health surveillance in Nigeria and Africa (2020–2025)

Disease/Domain	AI/ML Technique	Country/Setting	Key Outcome	Ref.
Monkeypox	Digital surveillance platform (SORMAS)	Nigeria	Improved timeliness/completeness of outbreak reporting vs. paper-based system	7
Routine immunisation	DHIS2 dashboard analytics	Nigeria	Enhanced timeliness/completeness of immunisation data reporting	11
COVID-19	Regression, ARIMA, ensemble ML models	Nigeria	Tree-based ML outperformed classical models (R^2 = 0.90) in case forecasting	8
Malaria	Nested cross-validated ML classifiers	Nigeria	Improved prediction of Pf antigen positivity from clinical/environmental data	16
Malaria (paediatric)	Supervised ML clinical algorithms	Nigeria	Increased sensitivity/specificity over standard IMCI-based triage	17
Tuberculosis	Bayesian inference/hotspot	South-west Nigeria	Predicted hotspots yielded ≥1.75× higher	19

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	geoportal		TB case-finding yield	
Tuberculosis adherence	3D ResNet deep learning (video)	Uganda (regional)	High sensitivity (~95%) for classifying medication-intake adherence	20

Source: Compiled by authors from cited literature [7,8,11,16,17,19,20]

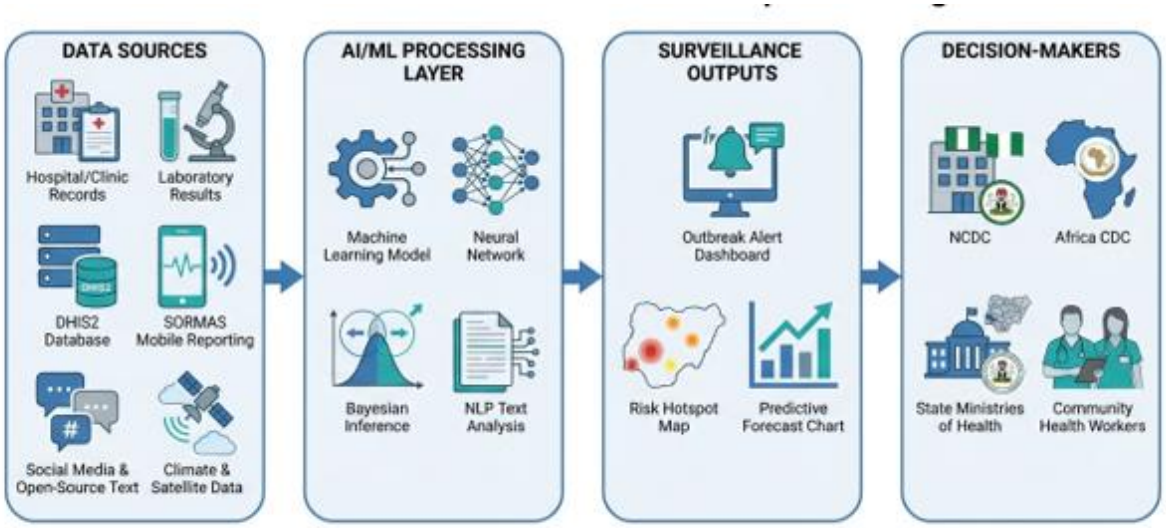


Figure 1. Conceptual framework of an AI-enabled public health surveillance pipeline in Nigeria.
Caption: Figure showing data inputs (facility/laboratory records, DHIS2, SORMAS, mobile/NLP-derived open-source signals, climatic/environmental data), an AI/ML processing layer (outbreak detection, risk prediction, hotspot mapping), and outputs feeding NCDC/Africa CDC decision-making and community-level response.
Sources: Adapted conceptually from references [4,3,7].

Challenges to AI-Enabled Surveillance in Nigeria and Africa

Despite documented gains, several structural barriers constrain the scale-up of AI in African public health surveillance. First, digital infrastructure remains uneven: average broadband internet speeds in Africa lag substantially behind the global average, and unreliable electricity continues to disrupt cloud-based analytics and real-time data synchronisation in many facilities [1]. Second, Nigeria's digital health ecosystem remains fragmented, with SORMAS, DHIS2, and the broader IDSR system frequently operating in parallel rather than as a fully interoperable architecture, limiting the completeness of datasets available for model training [3,6].

Third, a shortage of locally trained AI and data-science specialists constrains the development, validation, and maintenance of context-appropriate models; many predictive tools applied in African settings are trained on external datasets that may not generalise well to local epidemiological and sociodemographic conditions [3,6]. Fourth, ethical, legal, and governance

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ISSN: 2456-8643

frameworks for health-data privacy, algorithmic bias, and accountability remain underdeveloped across much of the continent, raising concerns about consent, data ownership, and equitable model performance across diverse populations [1,6]. Finally, funding for sustained AI infrastructure, as opposed to short-term pilot projects, remains limited, and cross-sectoral collaboration between ministries of health, academia, and technology developers is often ad hoc rather than institutionalised [4,9**]**. Table 2 shows the key challenges and corresponding mitigation strategies for AI-enabled public health surveillance in Nigeria/Africa, whereas Figure 2 presents the Radar/spider chart comparing the relative severity of five key barriers (infrastructure, data quality/interoperability, workforce capacity, ethics/governance, financing) to AI-enabled surveillance adoption across selected African sub-regions.

Table 2. Key challenges and corresponding mitigation strategies for AI-enabled public health surveillance in Nigeria/Africa

Challenge Domain	Description	Proposed Mitigation
Infrastructure	Unreliable electricity/internet; below-average broadband speeds constrain cloud-based analytics	Offline-first, low-bandwidth mobile applications; investment in rural connectivity and solar-powered facility ICT
Data quality/interoperability	Fragmented systems (SORMAS, DHIS2, IDSR) operating in parallel; incomplete, inconsistent facility-level data	National interoperability standards; unified health-data exchange architecture led by NCDC/Federal Ministry of Health
Workforce capacity	Shortage of local AI/data-science specialists; limited digital literacy among frontline health workers	Curriculum reform, in-service training, regional AI fellowships and Africa CDC workforce initiatives
Ethics and governance	Weak data-privacy regulation, algorithmic bias, unclear accountability for AI-informed decisions	Enforceable national AI-in-health ethical frameworks; bias auditing; alignment with Africa CDC guidelines
Financing	Reliance on short-term donor-funded pilots rather than sustained national budgets	Domestic budget allocation, public–private partnerships, regional pooled-procurement mechanisms

Source: Synthesised by authors from cited literature [1,3,4,6,9]

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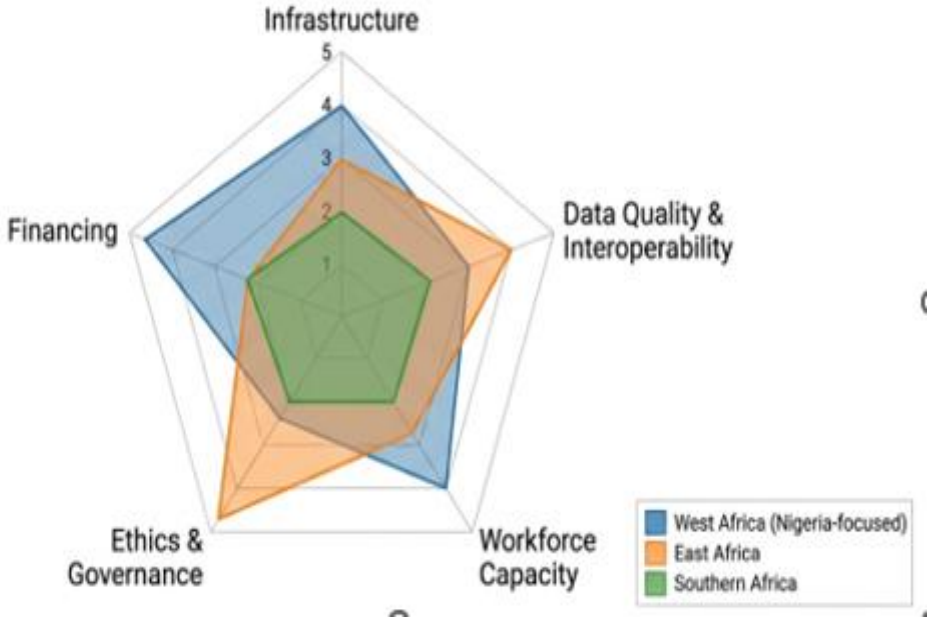


Figure 2. Radar/spider chart comparing the relative severity of five key barriers (infrastructure, data quality/interoperability, workforce capacity, ethics/governance, financing) to AI-enabled surveillance adoption across selected African sub-regions.
Sources: Adapted conceptually from references [1,6].

3. OPPORTUNITIES AND RECOMMENDATIONS

Notwithstanding these constraints, several converging opportunities position Nigeria and Africa to strengthen AI-enabled surveillance over the coming decade. Continental leadership from the Africa CDC, including its emerging ethical framework and emergency-response guidance, provides a coordinating mechanism for harmonising standards, data-sharing agreements, and AI governance across member states [1]. Nigeria's own experience integrating NLP-based local-language search terms into open-source epidemic intelligence platforms illustrates how context-sensitive adaptation can substantially improve outbreak-signal detection [14].

Investment in laboratory-medicine AI, diagnostic-support tools, and integration of AI curricula into medical, public-health, and computing education can build a sustainable local talent pipeline [23]. Strengthening routine disease-surveillance evaluation, as demonstrated in recent assessments of Nigeria's diphtheria and HIV surveillance systems, offers a template for embedding AI-readiness assessments into standard surveillance-system reviews [24,25]. Continued efforts to upgrade Nigeria's broader digital-health ecosystem provide the foundational architecture on which AI applications can be reliably layered [26]. Finally, public–private partnerships between government, academia, and Nigeria's growing health-technology start-up ecosystem can mobilise financing while ensuring that locally developed tools remain aligned with public-sector needs and equity goals [21,22].

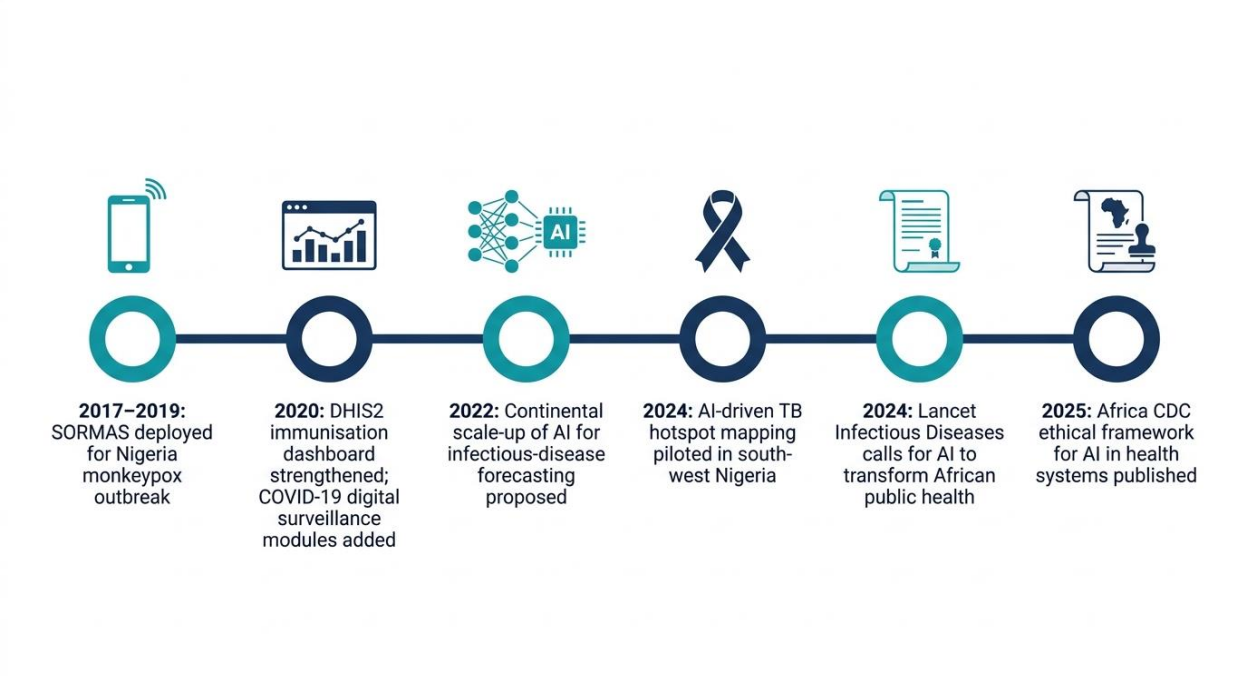
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ISSN: 2456-8643

Table 3. Comparative overview of major digital/AI-enabled surveillance platforms used in Nigeria

Platform	Primary Function	AI/Analytics Component	Ref.
SORMAS	Mobile case notification, contact tracing, outbreak management across 12+ priority diseases	Dashboard analytics; being extended with automated alert/reporting features	7, 10
DHIS2	Routine health information management, immunisation data module	Aggregated dashboard analytics supporting decentralised decision-making	11
NLP-based epidemic intelligence platform	Open-source/media scanning for early outbreak signals	Natural language processing and automated classification of outbreak-related text	14
Bayesian/geoportal TB hotspot tool	Community-level TB risk mapping for active case-finding	Bayesian inference model with geospatial visualisation	19

Source: Compiled by authors from cited literature [7,10,11,14,19]



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Figure 3. Timeline of key milestones in AI-enabled public health surveillance development in Nigeria and Africa, 2017–2025, from initial SORMAS deployment during the monkeypox outbreak through to recent continental AI-ethics guidance.
Sources: Adapted conceptually from [1,4,7].

4. CONCLUSION

AI is progressively reshaping public health surveillance across Nigeria and Africa, extending from digitised outbreak-management platforms such as SORMAS and DHIS2 to machine learning-based forecasting of malaria, tuberculosis, cholera, monkeypox, and COVID-19. The evidence reviewed demonstrates measurable gains in the timeliness, precision, and targeting of surveillance and response activities. However, realising the full transformative potential of AI requires deliberate, coordinated investment in digital infrastructure, interoperable data systems, local AI workforce capacity, and robust ethical governance frameworks. Continued leadership from national bodies such as the NCDC, alongside continental coordination through the Africa CDC, will be essential to ensure that AI-enabled surveillance systems are sustainable, equitable, and contextually validated for African epidemiological realities.

Conflict of Interest

The authors declare no conflict of interest.

Source of Funding

This review received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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