Geo-Ai for Predicting Malaria Outbreaks and Optimizing Preventive Interventions in Uganda

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SUMMARY

Title: Background:

Malaria remains Uganda's highest-burden disease, with over 12 million annual cases reported each year. Climate variability, stagnant-water ecosystems, and shifting human mobility patterns continue to undermine reactive control programs. To address these challenges, we propose a Geo-AI system that integrates spatial epidemiology, machine learning, and predictive mapping to anticipate malaria outbreaks and guide precision deployment of preventive interventions.

Methods:

We will fuse multi-source datasets including routine DHIS2 malaria incidence reports, community rapid diagnostic test (RDT) results, and outpatient surveillance data. Environmental variables such as rainfall, vegetation indices, soil moisture, and temperature anomalies will be extracted from Sentinel satellite imagery. Human mobility flows, road networks, and facility readiness data will be incorporated to capture transmission dynamics and accessibility

constraints.

The AI pipeline will employ spatio-temporal deep learning models (LSTMs combined with Bayesian hierarchical frameworks) to detect hidden correlations between climate patterns and malaria case spikes. Random Forest and XGBoost classifiers will be applied to predict village-level hotspots, with explainable AI techniques highlighting key outbreak drivers. Graph-based optimization algorithms will then simulate cost-effective allocation of interventions—bed nets, indoor residual spraying (IRS), and RDT kits—under resource and logistics constraints. An interactive GIS dashboard will visualize real-time risk layers, issue early warning alerts up to six weeks in advance, and support intervention planning in partnership with the Uganda National Malaria Control Division.

Results:

Retrospective validation using outbreak data from 2018–2024 is expected to demonstrate predictive accuracies above 85%. The system will generate dynamic hotspot maps at parish resolution, enabling proactive targeting of high-risk communities. Simulation studies predict up to a 30% reduction in outbreak caseloads compared to the current blanket distribution strategy. Case studies from northern Uganda will showcase faster and more equitable delivery of preventive resources, particularly in underserved rural populations.

Conclusion:

By merging GIS, AI, and health surveillance, this approach transforms malaria control in Uganda from reactive treatment to predictive prevention. It empowers policymakers with an

evidence-driven

decision-support tool that optimizes scarce resources, saves lives, and offers a scalable model for

tackling vector-borne diseases across Africa.