

Risk Modelling of *Clavibacter nebraskensis*, an Emerging Pest threat in Uganda

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Introduction

- Goss's bacterial wilt, caused by the seed-transmitted bacterium *Clavibacter nebraskensis*, is an emerging phytosanitary threat to maize production in Africa.
- First confirmed in South Africa in February 2025 and now established in four provinces (Free State, North-West, Gauteng, Eastern Cape) with ongoing delimiting surveys (IPPC, 2025).
- The pathogen has not yet reached Uganda or East Africa.
- South Africa's dominant role in maize seed and grain exports creates a significant introduction pathway via contaminated planting material.
- In Uganda, maize is the principal staple crop, contributing over 40% of daily caloric intake, supporting more than two million smallholder households, and generating US\$132.7 million in export revenue (2023).
- Potential introduction could cause 30–60% yield losses, leading to estimated annual economic damages of US\$250–350 million and severe threats to food security and rural livelihoods.
- This study addresses the lack of spatially explicit risk assessment by producing high-resolution environmental suitability and composite risk maps to guide preventive biosecurity by Uganda's National Plant Protection Organization (MAAIF).

Methodology

- Open source maxnet MaxEnt species distribution modelling was applied nationally.
- Occurrence records were cleaned and thinned to a 10 km minimum distance to reduce spatial bias.
- From 19 WorldClim v2 bioclimatic variables, five were selected after screening (correlation $|r| \geq 0.80$, VIF < 10, jackknife TSS-guided pruning): BIO1, BIO4, BIO5, BIO12, BIO15.
- Models were tuned with ENMeval using spatial block cross-validation; optimal settings (lowest AICc) were used for final fit.
- A 10-replicate bootstrap ensemble provided mean suitability and uncertainty; Multivariate Environmental Similarity Surface (MESS) assessed extrapolation risk.
- Weighted composite risk index (CRI = $0.45 \times \text{Suitability} + 0.25 \times \text{Host} + 0.18 \times \text{Production} + 0.12 \times \text{Pathway}$) integrated suitability with SPAM 2020 maize/sorghum/sugarcane layers and inverted travel time to market.
- Outputs were masked to Uganda's 132 districts for zonal statistics.

Results and discussion

- Results show a clear south-to-north gradient in both environmental suitability and composite risk.
- Highest suitability occurs in the south-western highlands (Kisoro, Rubanda, Kabale, Rukiga, Kanungu, Rukungiri, Ntungamo) and Lake Victoria basin/central-eastern corridor (Wakiso, Mpigi, Mukono, Buikwe, Masaka, Kalungu, Lwengo, Rakai, Kyotera).
- These areas feature humid, warm conditions favourable to pathogen survival in residue, rain-splash dispersal, and infection via leaf wounding.
- Northern and north-eastern districts (Karamoja sub-region and Acholi/West Nile) exhibit consistently low suitability due to drier, less favourable climates.
- CRI amplifies risk in maize-intensive zones with strong market connectivity.
- District-level mean CRI averaged 0.283 (SD = 0.106, range 0.132–0.595) across 132 districts.
- Top-decile hotspots (CRI_mean ≥ 0.442 , 90th percentile) include 15 priority districts: Jinja (0.595), Lwengo (0.543), Kyotera (0.536), Rakai (0.497), Iganga (0.494), Bukomansimbi (0.473), Kabale (0.471), Ntungamo (0.467), Masaka (0.465), Mitooma (0.459), Lyantonde (0.448), Rwampara (0.445), Sheema (0.444), Rukiga (0.442), and Isingiro (0.442).
- These hotspots align closely with Uganda's major maize production belts.

Relevance of the study

- Provides Uganda's NPPO with a robust, actionable tool for preventive biosecurity.
- Hotspots and CRI thresholds enable targeted Risk-Based Surveillance: intensified seed inspections, import certification, early detection surveys, and farmer awareness in high-risk districts.
- Focusing resources where suitability, host availability, and trade converge maximises efficiency and minimises establishment risk.
- Open-source R workflow (maxnet + ENMeval) is reproducible and scalable to EAC/COMESA countries.
- Supports Uganda Vision 2040, NDP IV, UCSATP, and SDGs 1, 2, 13 by protecting a critical staple crop.
- Demonstrates proactive, climate-informed pest risk analysis before first detection.
- Offers a replicable model for safeguarding maize systems across sub-Saharan Africa against transboundary threats.

Predict before it spreads. Map risk before loss occurs.

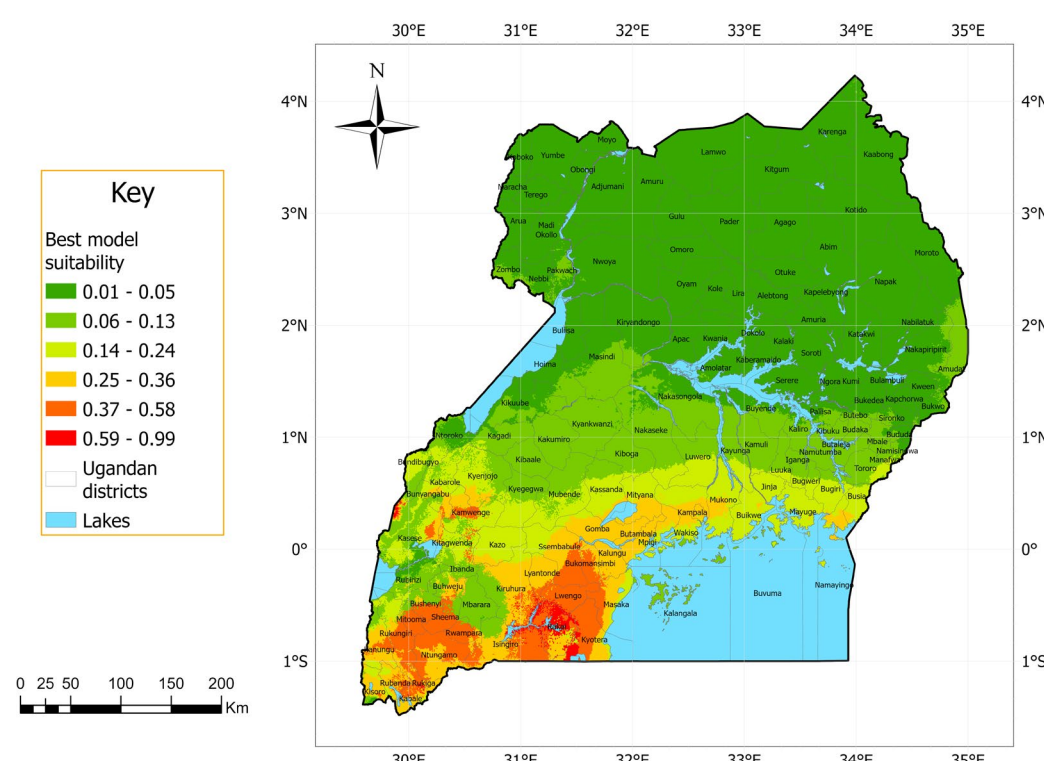


Figure 1: Predicted ecological suitability for *Clavibacter nebraskensis* establishment across Uganda based on the open source MaxEnt species distribution modeling.

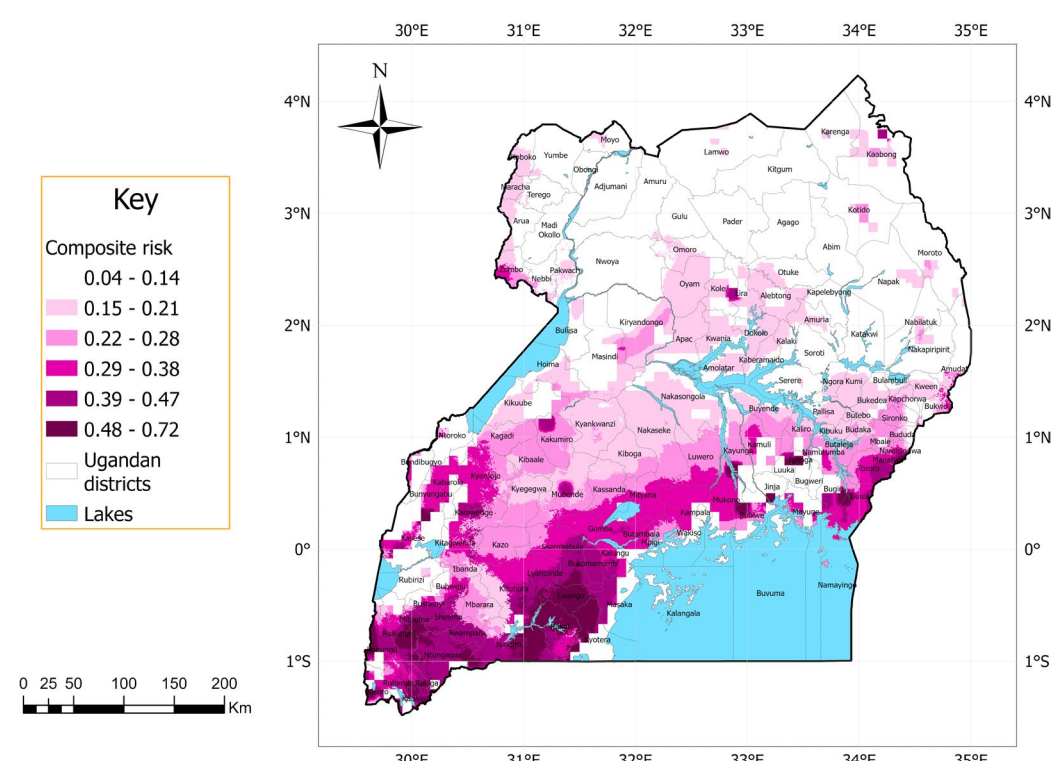


Figure 2: Composite Risk Index (CRI) map showing district-level establishment risk of *Clavibacter nebraskensis* across Uganda. Source: Boniface / NPPO Uganda