



UMEÅ UNIVERSITY

Umeå University Medical Dissertations New Series no. 2425

# Integrating spatial, classical and social epidemiology, machine learning, and qualitative approaches to understand childhood stunting in the Northern Province of Rwanda

Albert Ndagijimana

## Academic dissertation

Which, with the due permission of the Vice-Chancellor of Umeå University for the examination for the Degree of Doctor of Philosophy, is presented for public defence in ULED.A.310 - Triple Helix, Universitetsledningshuset, Umeå University on Friday, 12 June, 2026 at 09:00.

Link to participate via Zoom: <https://umu.zoom.us/j/67871831305>

The thesis will be defended in English.

Faculty opponent:

Professor Per Kallestrup, Department of Public Health - Institute of General Medical Practice, Aarhus University, Denmark

---

Department of Clinical Sciences

**Organisation**

Umeå University  
Department of Clinical Sciences

**Document type**

Doctoral thesis

**Date of publication**

29 April 2026

**Author**

Albert Ndagijimana

**Title**

Integrating spatial, classical and social epidemiology, machine learning, and qualitative approaches to understand childhood stunting in the Northern Province of Rwanda

**Abstract****Background**

In Rwanda, childhood stunting has declined over the last two decades, yet the Northern Province remains a high-burden area, an apparent contradiction given its fertile soils and robust agricultural activity. This thesis sets out to understand that disconnection. Rather than relying on national averages or single-discipline explanations, it asks where stunting concentrates, which factors are most influential and modifiable, and what the key caregivers' experiences are behind the fact that available resources and programs do not translate into better child growth.

**Methods**

A population-based cross-sectional study was conducted among 601 households with children aged 1–36 months across all five districts of Northern Province. Maternal, child and household characteristics were collected using structured questionnaires. Climatic, environmental and agroecological data were collected from remote sources. Parents were separately reached through focus group discussions. The design integrated five components: (1) spatial statistics to test randomness and identify sector-level hotspots; (2) machine learning to quantify the roles of climatic and environmental features alongside caregiving proxies; (3) multivariable logistic regression to determine modifiable factors; (4) wealth-inequality analysis to identify contributors to pro-poor inequalities; and (5) reflexive thematic analysis of gender-segregated focus groups to explore the caregivers' experiences and understanding of childhood stunting risk in the study area.

**Results**

The stunting prevalence was 27.1% among children 1-36 months. Its distribution was non-random and clustered, with statistically significant hotspots in three districts of the province. The machine-learning model indicated that location, in combination with climatic and environmental features, explained a large share of the variability in child low height-for-age. The multivariable regression analysis identified several modifiable household-level risk factors, including male children, maternal stature, inadequate breastfeeding, female-headed household, and inadequate handwashing facilities. Inequality analysis showed that the burden of stunting falls disproportionately on households within the poorest quintiles, with partners involved in non-skilled/unemployment and food insecurity. Exploring parents' experiences and understanding of childhood stunting, four main themes emerged: power struggles and broken care undermining child nutrition, vulnerabilities across the first 1,000 days shaping stunting trajectories, the paradox of plenty where livestock and food don't nourish children, and fragile substitute care leaving children behind.

**Conclusion**

Childhood stunting in the Northern Province of Rwanda remains complex with spatial clustering, many hidden and localised climatic and environmental pressures intersecting with household behaviours, caregiving constraints, and poverty, preventing available resources from reaching the child's plate. The thesis lists several possible venues to move the needle on stunting prevention in the study area.

**Keywords:** Stunting, undernutrition, spatital, inequalities, machine learning, factors, qualitative, Rwanda

**Language**

English

**ISBN**

978-91-6850-025-6 (print)  
978-91-6850-026-3 (pdf)

**ISSN**

0346-6612

**Number of pages**

65 + 5 papers