Spatio-temporal Patterns of Malaria Incidence in Rwanda

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Background

- Despite the declining malaria incidence result of intense interventions, the potentials for transmission remain in high endemic areas of Rwanda.

- Malaria transmission is clustering in small areas where populations share the same factors of transmission (climate conditions an socio-economic characteristics).

- As Rwanda is nearly to malaria elimination phase, local interventions have to be more targeted to the areas of the most needs.

- To achieve this, an Integrated Vectors Management Strategy (IVM) has been adopted since 2013: based on local ecology, malaria epidemiology and socio-economic factors to eliminate pockets of malaria transmission by effective interventions targeted to the high risk areas.
Rationale for research

- Previous studies by Rulisa et al. (2013) and Tuyishimire (2014) focused on malaria clustering using household data.

- These studies were not able to identify the hotspots malaria to guide national malaria control program at country level.

- Identifying malaria hotspots can support local initiative of (IVM strategy) for malaria elimination.

- The research findings from this study can help to end the epidemics malaria in Rwanda by 2030 (SDG 3.3).
Study area

Geographically, Rwanda has two distinct malaria ecozones:

- **Highlands** characterized by low and unstable malaria transmission.
- **Stable and high malaria transmission** in low land areas.

Spatial distribution of malaria prevalence in Rwanda
Materials and methods (1)

- **Delineation of health centre catchment areas**
  - In Rwanda, malaria cases are reported at health centre level.
  - Health centre shapefiles (GPS coordinates) were acquired from Ministry of Health.
  - A geographical information system (GIS) was used to delineate the health centre catchment areas using ArcGIS10.6 software.

- **Testing the spatial autocorrelations**
  - We drew on Tobler’s law of spatial autocorrelation by which near things are more similar (Tobler, 1970).
  - Global Moran’s I statistics were calculated to test whether malaria incidence data is clustered or not.
A high positive z-score and a small p-value indicate a spatial cluster of high malaria incidence.

A low negative z-score and a small p-value indicate a spatial cluster of low malaria incidence.
## Global Moran’s I summary for different years

<table>
<thead>
<tr>
<th>Year</th>
<th>Moran's Index</th>
<th>Expected Index</th>
<th>Variance</th>
<th>z-score</th>
<th>p-value</th>
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<td>0.652963</td>
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</table>
Hotspot analysis:

- **Optimized Hotspots Toolset** was used to identify the hotspots of malaria incidence and analyse the spatio-temporal patterns at health centre catchments level.

- This tool is commonly used in spatial epidemiology to identify the clustering of high and low values in malaria incidence point data.

Box-plots

- IBM SPSS software was used to generate box-plots that compare the intensity of inter-annual variation of malaria incidence.
Results: malaria hotspots identified

- Statistically significant hotspots are found in low lands.
- The coldspots are mainly located in highlands.
Statistically significant hotspots of malaria incidence have been detected in lower lands of Rwanda.

These hotspots form the zones that are heavily affected by malaria burden.

Highlands are the coldspots of malaria transmission.

Reduction of extent of coldspots and shifting patterns of hotspots to higher elevation (especially in 2015 and 2014).

Rwandan highlands are experiencing climatic changes and variability leading to epidemic malaria.
Spatial-temporal hotspots of malaria incidence

- An **increasing size** of malaria hotspots extent was mainly observed in 2014 and 2015.

- Temporal shifts of hotspots provides evidence of **climate change and variability impacts on malaria transmission**.

- This period coincide with the 2014-2015 strongest El Niño event ([FAO, 2015](#)).

- Identified malaria hotspots may be linked to local geographic conditions (vectors breeding sites and climate suitability).

- Other driving factors may relate to **socio-economic and environmental changes associated with agricultural practices in irrigated areas** ([Bizimana et al. 2015](#)).

- Stable malaria hotspots imply that exiting interventions are not likely to eliminate malaria transmission in highly endemic areas.
Inter-annual variation of malaria incidence

- **Box-plots** show the interannual variability of malaria cases.
- **Thick black horizontal line**: indicates the median value of malaria incidence for each year.
- **Top ends of box-plots** indicate the upper (75%) quartiles.
- **Lower ends of the box-plots** mark the lower (25%) quartiles.
- **Upper and lower whiskers** represent maximum and minimum values of reported malaria cases each year.
- The larger the interquartile range, the higher is the number of malaria cases.

- The high number of malaria cases was reported in 2009 and 2010 and very recently in 2015 and 2016.
A significant increase of malaria was reported in 2009 and 2010 and in 2015 and 2016.

Malaria increase in 2009 was linked to a limited coverage of LLINs (Karema et al. 2012).

But also, climate variability linked to El Niño of 2009-2010 cannot be overlooked.

A sharp increase between 2015 and 2016 may be associated with the strongest ENSO (Jacox et al. 2016).

Previous studies discovered an association between malaria and El Niño in Rwanda highlands (Loevinsohn 1994).
Concluding remarks

- This is a first attempt to apply a spatial statistic approach to analyze the hotspots of malaria incidence in Rwanda.

- Hotspot analysis is an effective tool for identifying priority areas for malaria interventions in Rwanda.

- Persistent hotspots overlap with the location of vector-breeding sites that might favor higher exposure to mosquitoes’ bites.

- Stable hotspots have been found to be predictive of future malaria incidence and may seed transmission in surrounding areas.

- Unstable hotspots emerge during the peak transmission season and are not necessarily sustained throughout the year.

- This study provides baseline information for targeting interventions in the areas of the most need.
Concluding remarks

Some limitations

❑ This study has not integrated entomological and malaria parasitological survey data.

❑ As malaria incidence data was aggregated at health centres level, the results may be subject to caution due to inconsistencies in malaria reporting.

❑ Limitation of data coverage and completeness: private health facilities were not included (underestimation of malaria incidence).
Future directions for research

❑ A further study at household level by using malaria prevalence and household characteristics, origin of patients and Entomological Inoculation Rate (EIR) may help to improve the identification of malaria hotspots.

❑ Recognizing that malaria transmission varies across landscapes, a Geographically Weighted Regression (GWR) can be used to identify the drivers of malaria incidence in each hotspot (if data are locally available).
Thank you for attention

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