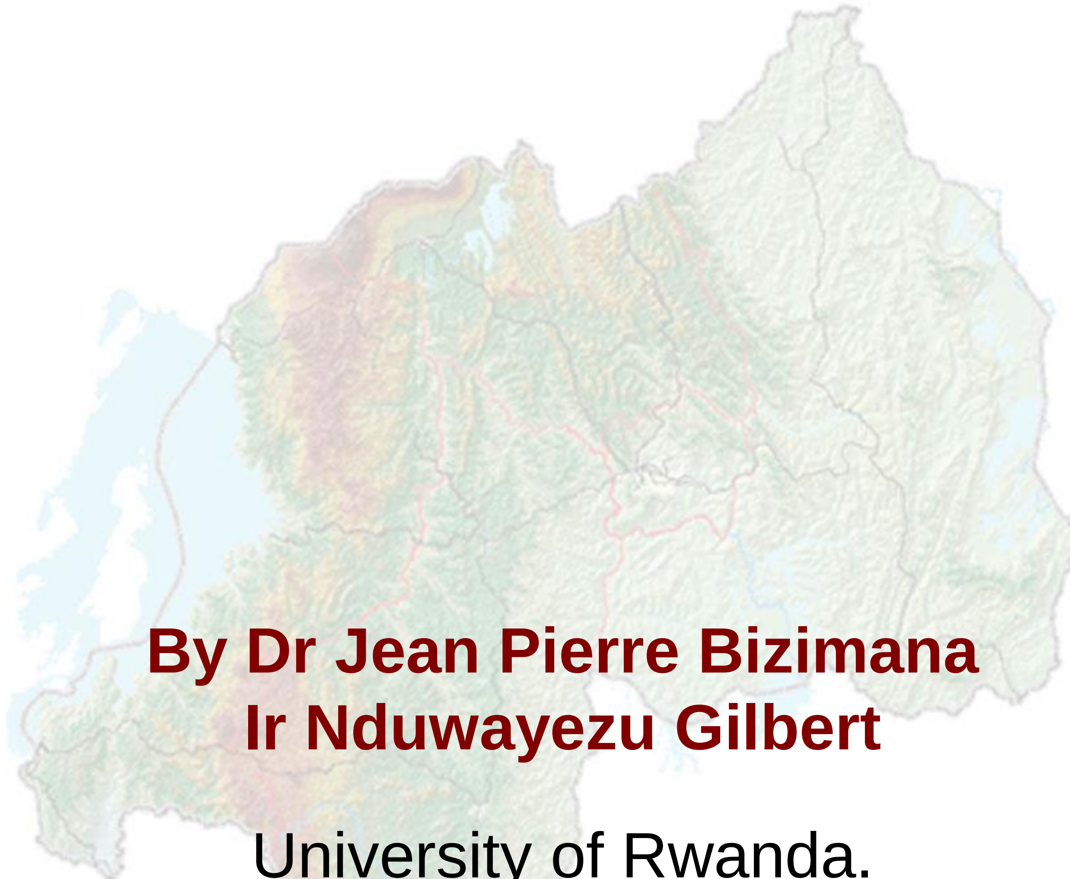
Spatio-temporal Patterns of Malaria Incidence in Rwanda



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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

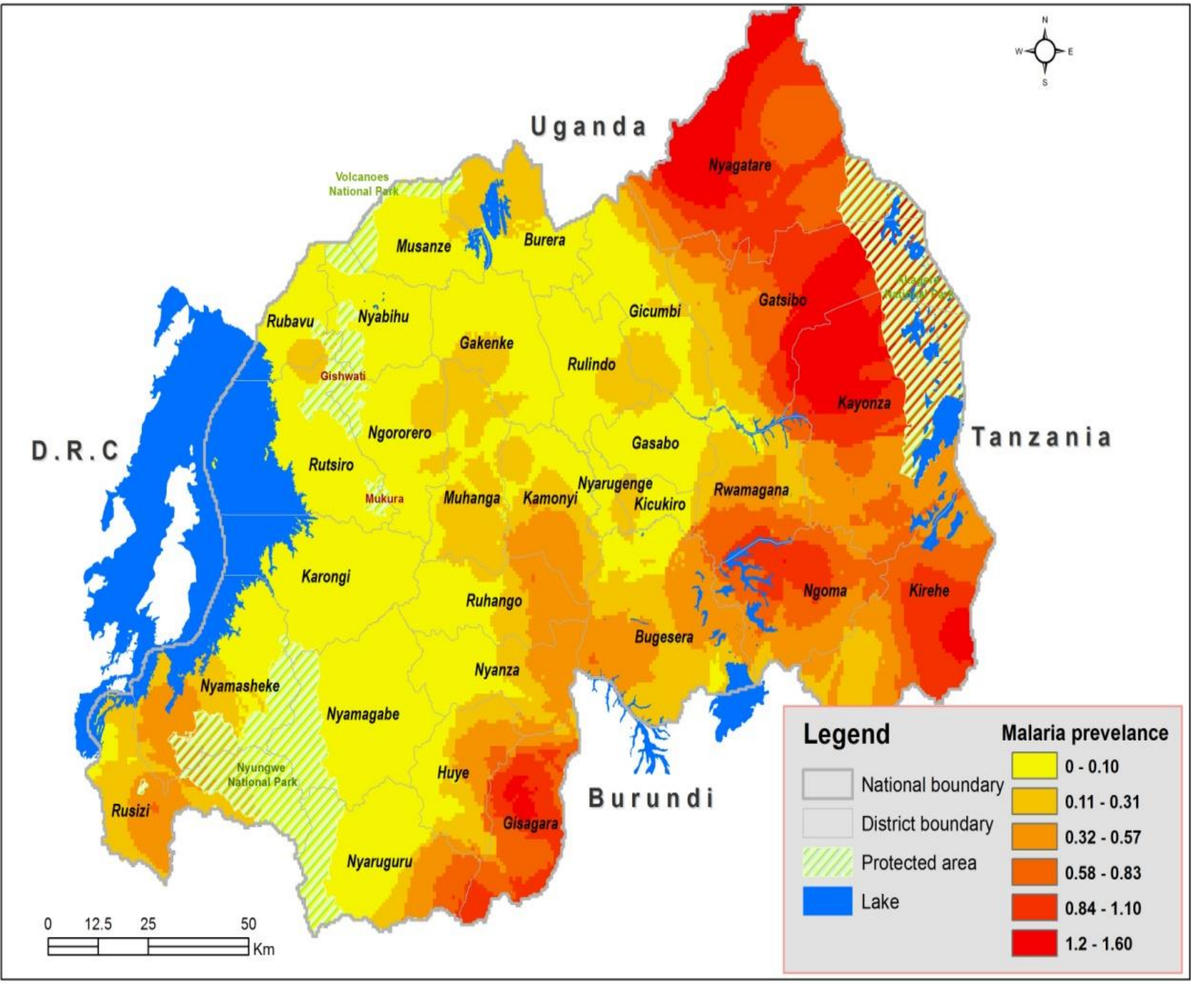
- Previous studies by **Rulisa *et al.*** (2013) and **Tuyishimire** (2014) focused on malaria clustering using household data.

- 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



- Spatial distribution of malaria prevalence in Rwanda
- Geographically, Rwanda has two distinct malaria ecozones
- **Highlands** characterized by low and unstable malaria transmission.
- Stable and high malaria transmission in **low land areas.**

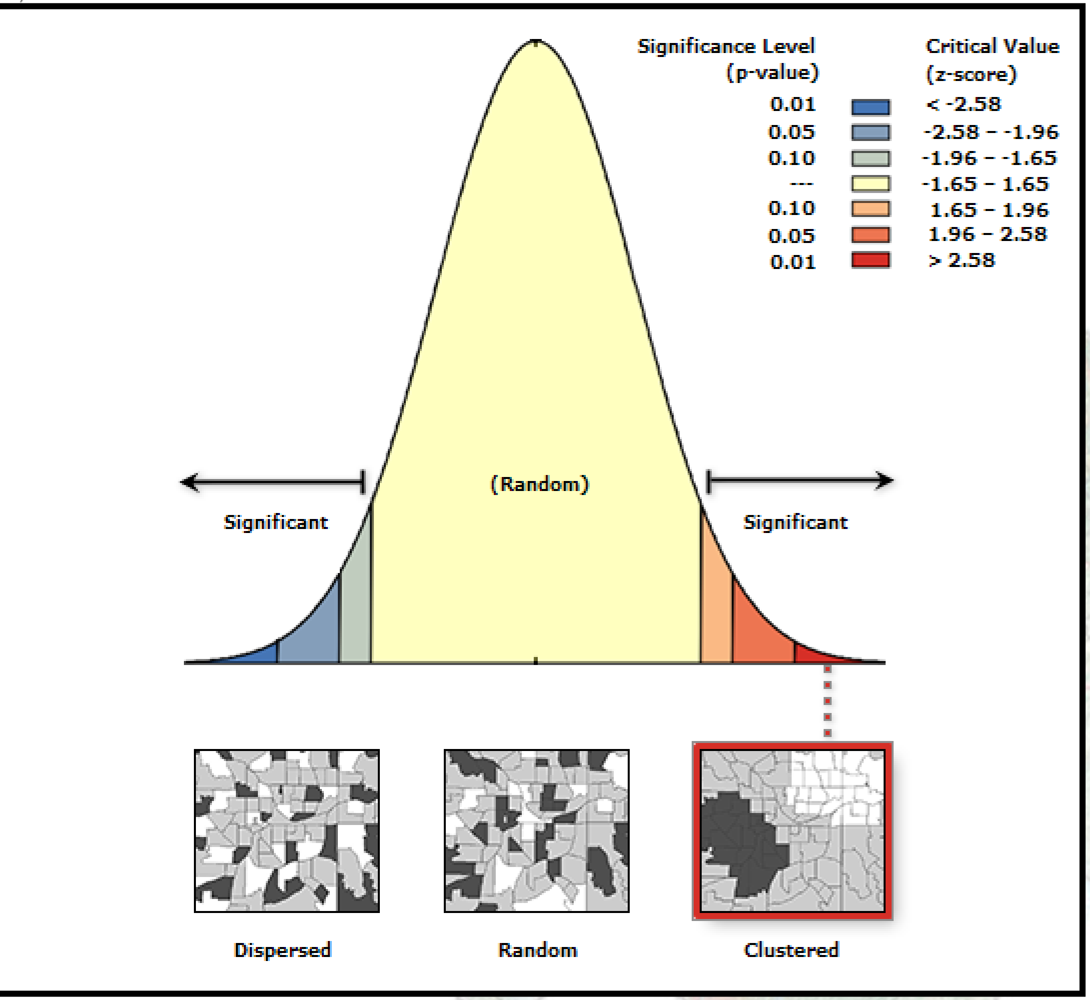
Spatial distribution of malaria prevalence in Rwanda

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 drawn 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.

Graph of clustered malaria pattern in 2016



- 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

Year	Moran's Index	Expected Index	Variance	z-score	p-value
2016	0.652963	-0.002725	0.000419	32.0303	0.00
2015	0.454346	-0.002725	0.000433	21.9557	0.00
2014	0.511968	-0.002725	0.000436	24.6559	0.00
2013	0.432895	-0.002725	0.000433	20.9419	0.00
2012	0.403964	-0.002725	0.000432	19.5609	0.00
2011	0.376466	-0.002725	0.000416	18.5894	0.00
2010	0.327028	-0.002725	0.000432	15.8592	0.00

Materials and methods (4)

❑ Hotspot analysis:

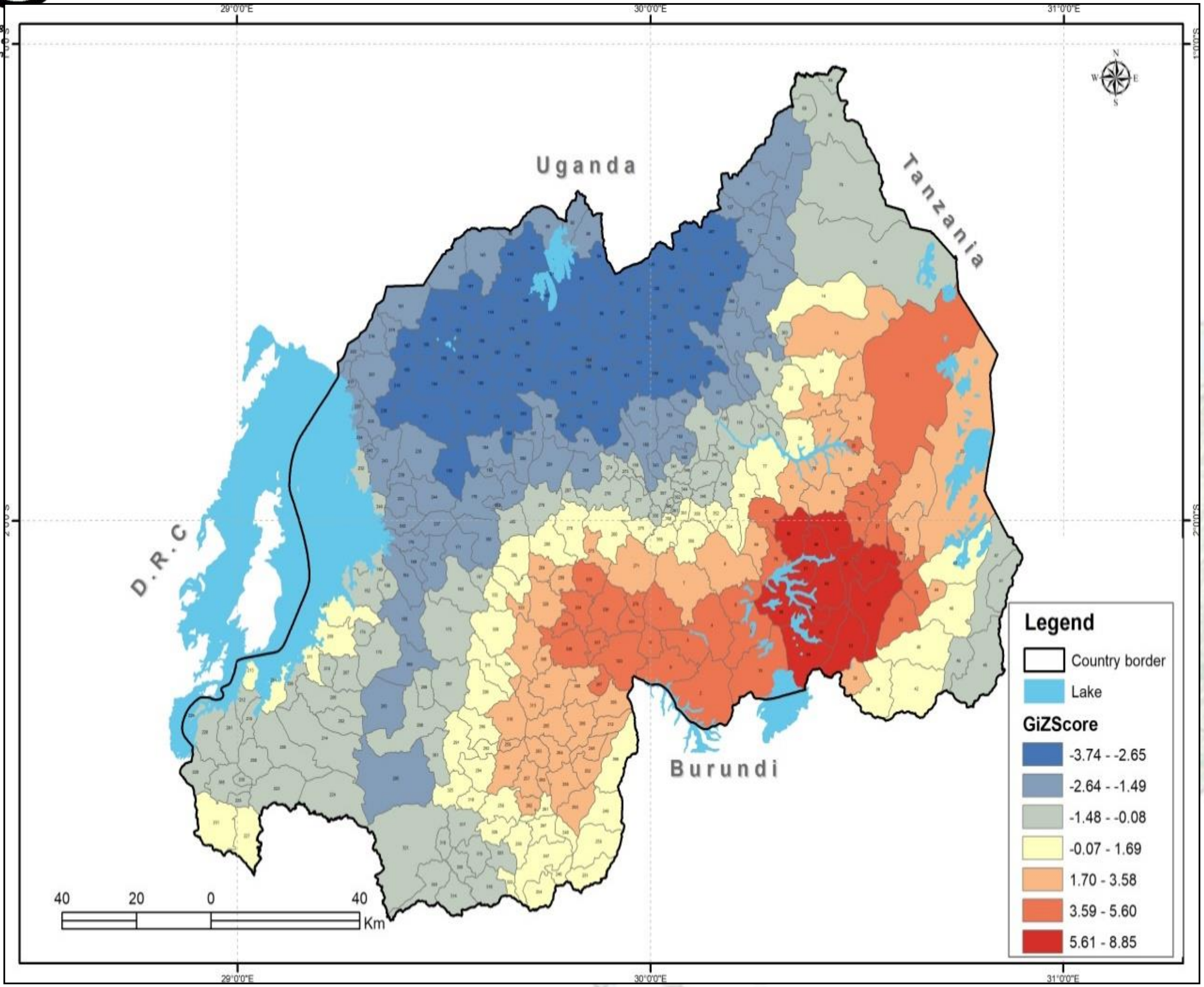
- ❖ Optimized Hotspots Toolset was used to identify the hotspots of malaria incidence and analyse the spatio-temporal patterns at health centre catchments level

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

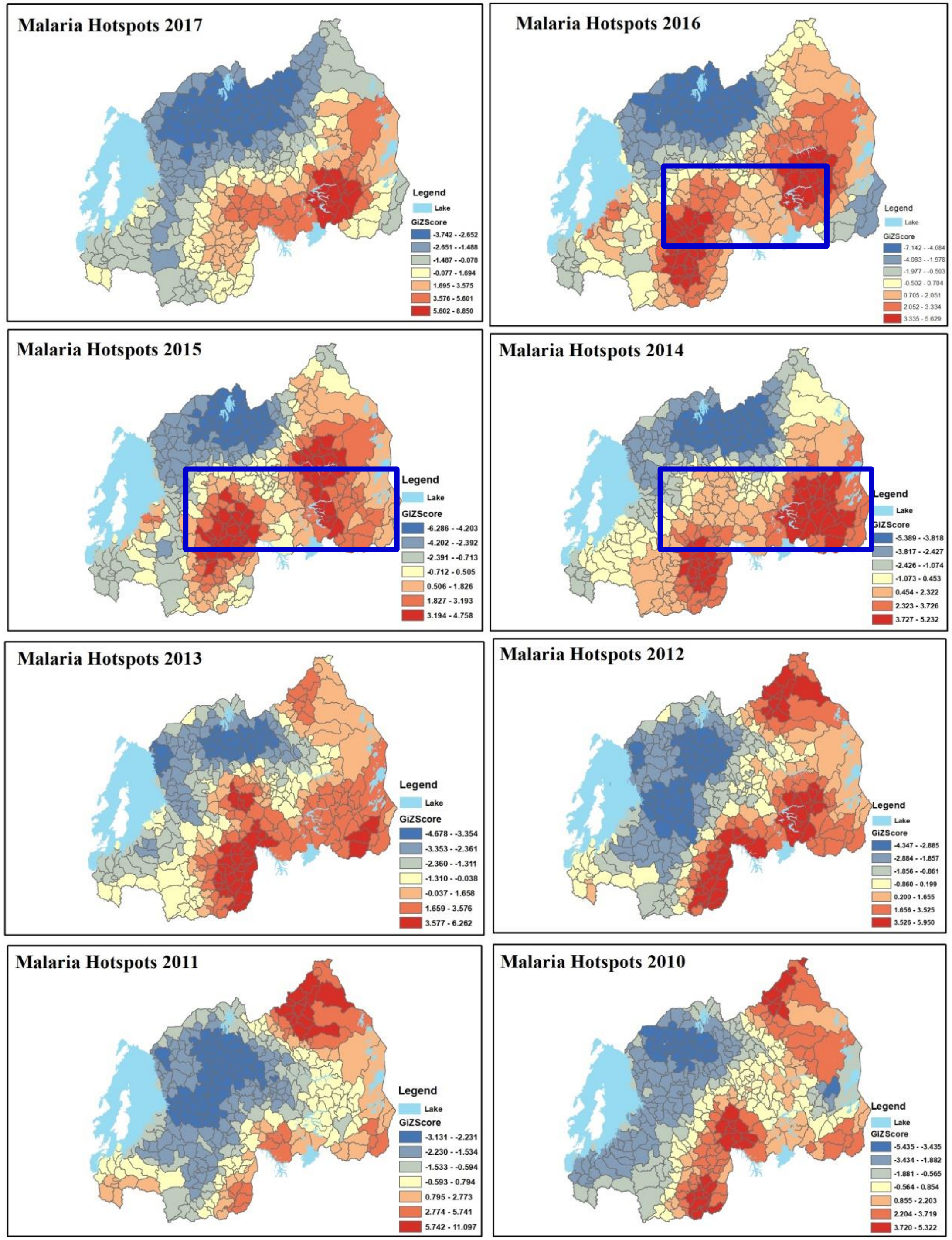
❑ Box-plots

- ❖ 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

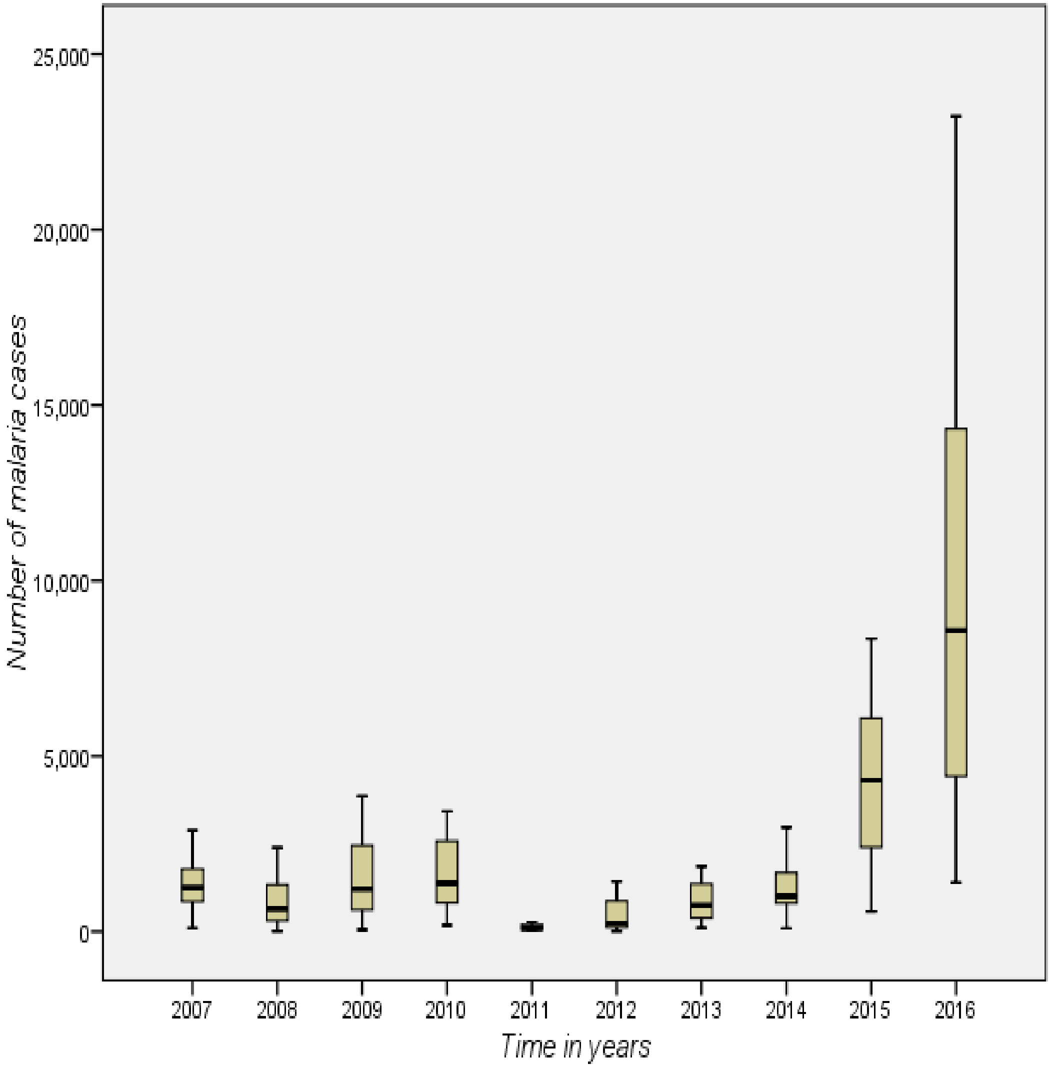


- **Statistically significant hotspots** of malaria incidence have been detected in lower lands of Rwanda.
- These hotspots form the zones that are heavily affected by malaria burden.
- Highlands are the **coldspots** of malaria transmission
- Reduction of extent of coldspots and shifting patterns of 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.

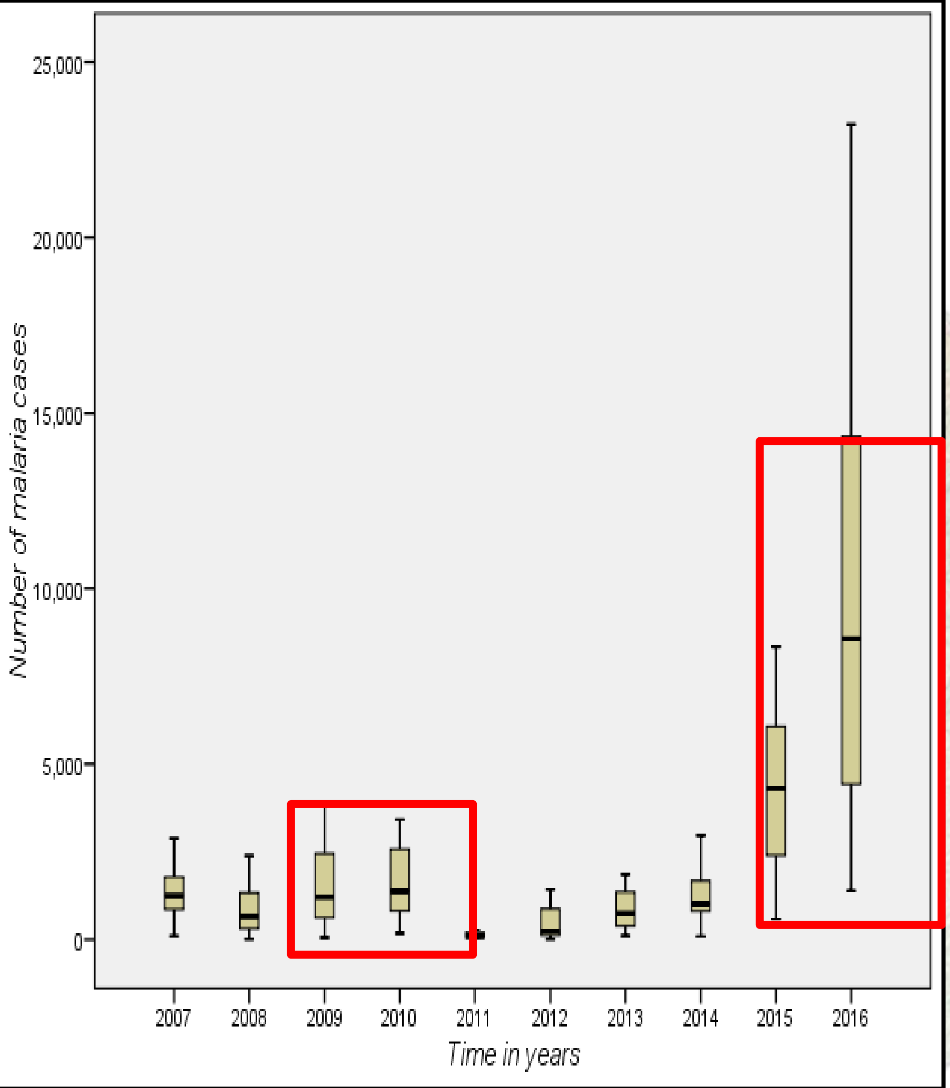
Inter-annual variation of malaria incidence



- Box-plots shows 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**

Inter-annual variation of malaria incidence



- 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 fist 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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