Predictive mapping based on routine surveillance data: Lessons from dengue risk mapping in Vietnam

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Introduction

• Dengue – a viral disease of humans prevalent in the tropics caused by Dengue virus (DENV 1-4), transmitted by *Aedes* mosquitoes

Dengue risk map (Source: [https://www.cdc.gov/dengue/epidemiology/index.html](https://www.cdc.gov/dengue/epidemiology/index.html))

• The viruses cause febrile diseases ranging from asymptomatic fevers to more severe illness associated with secondary infections with heterotypic DENV

• Disease has expanded geographically since the 1950s probably due to:
  • Urbanization
  • Tourism and migration
  • Climate change
Extensive studies on DEN risk in SEA and Latin America

- Risk factors: temperature, rainfall and humidity
- Lessons for other regions to learn from as DEN risk expands globally

However:

- Not much has been done to assess interactions between meteorological variables and geographical factors – altitude, land use/land cover, etc.
- Existing risk maps do not show changes in risk with season and land use change

Dengue in Vietnam (94 million people): outbreak every year, large outbreak in 2017 with over 130,000 case and 30 deaths

Pestforecast project – spatio-temporal analysis and risk-mapping of climate sensitive diseases including DEN in Vietnam
Methods

• We collated secondary data:
  - DEN surveillance from Provincial Preventive Medicine Center, Ministry of Health (MoH), for 2001-2012
  - Human population from the General Statistics Office, Ministry of Planning and Investments (MPI)
  - Meteorology from Institute of Meteorology, Hydrology and Climate Change, Ministry of Natural Resource and Environment (MONRE)
  - Land use land cover from MODIS database
  - Altitude from MODIS

• All the data summarized by province (n=63) and month (n=12) to give 9,072 records
Methods

• Descriptive analyses:
  o Generated mean monthly DEN incidence by province in 100,000 people as:

\[
\text{Incidence} = \frac{\text{cases}}{\text{population}} \times 100,000
\]

  o Principal component analysis to filter meteorological data
  o Distribution of DEN incidence by defined levels of geographical predictor variables

• Modelling using hierarchical Bayesian model (INLA) to account for:
  o Spatial autocorrelation
  o Temporal autocorrelation
  o Spatio-temporal interactions
Results – mean DEN incidence

Mean incidence:
- 6.94 cases/100,000
- SD 14.49

Annual DEN incidence 2001 - 2012
Results – principal component analysis

Met data

- Met data had 13 variables, some correlated
- Principal component analysis clustered met variables into about 4 groups
- Principal variables identified and used in the regression model:
  - Humidity, rainfall, minimum temperature and evaporation

Results of the principal component analysis of meteorological variables
Methods – monthly DEN incidence at levels of geographical factors

Altitude

Wetlands

Urban settlements

Area under forests

Area under savanna grassland

Area under crops
Results – posterior parameter distributions from the hierarchical spatiotemporal Bayesian model fitted to data

Final model generated and used for risk mapping

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>2.5% quantile</th>
<th>97.5% quantile</th>
<th>Mode</th>
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<tbody>
<tr>
<td>Fixed effects:</td>
<td></td>
<td></td>
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<tr>
<td>Minimum temperature</td>
<td>-0.150</td>
<td>0.006</td>
<td>-0.161</td>
<td>-0.138</td>
<td>-0.150</td>
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<tr>
<td>Minimum temperature (squared)</td>
<td>0.010</td>
<td>0.000</td>
<td>0.010</td>
<td>0.010</td>
<td>0.010</td>
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<td>Rainfall</td>
<td>0.299</td>
<td>0.002</td>
<td>0.295</td>
<td>0.303</td>
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<tr>
<td>Rainfall (squared)</td>
<td>-0.034</td>
<td>0.000</td>
<td>-0.035</td>
<td>-0.034</td>
<td>-0.034</td>
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<tr>
<td>Altitude</td>
<td>-0.001</td>
<td>0.001</td>
<td>-0.002</td>
<td>0.001</td>
<td>-0.001</td>
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<tr>
<td>Urban areas</td>
<td>0.733</td>
<td>0.012</td>
<td>0.710</td>
<td>0.756</td>
<td>0.733</td>
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<td>Hyperparameters:</td>
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<td>IID</td>
<td>1.118</td>
<td>0.291</td>
<td>0.651</td>
<td>1.786</td>
<td>1.016</td>
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<td>BYM model</td>
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<td>0.736</td>
<td>0.415</td>
<td>3.230</td>
<td>0.926</td>
</tr>
</tbody>
</table>
Results – risk maps ($\log$ DEN incidence/pop)

Dry season (Jan – Feb)  
Wet season (May – November)
Discussion and conclusions

• Our analyses combine met and geographical data on land use/land cover and altitude to show **seasonal dynamics in DEN risk**

• Statistical model developed can be used for **forecasting** by changing rainfall and temperature values

• **Space-time interactions** significant -- risk in the endemic areas evolves much faster and to much higher levels during the monsoon periods than non-endemic areas

• Findings/maps useful for **surveillance and targeted interventions**
Acknowledgements

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CGIAR Research Program on Climate Change, Agriculture and Food Security

CGIAR Research Program on Agriculture for Nutrition and Health
better lives through livestock

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