Land use change and the risk of selected zoonotic diseases: Observations from a case study in an arid/semi-arid area in Kenya

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Introduction

• Climate and demographic changes and food insecurity

• Irrigation – being used to boost food production in arid/semi-arid areas

• Effects: major trade-offs in ecosystem services

  ➢ More food produced (provisioning services) at the expense of biodiversity and regulatory services (disease, flooding, erosion)

  ➢ Disease transmission contributed by:
    o Standing water masses associated with irrigation
    o Human settlements and periurban settlements
    o Livestock diversity – more small than large ruminants
Objectives

- The effects of irrigation on:
  - Ecosystem changes – diversity of hosts
  - Risk of vector-borne and other zoonotic diseases

Irrigated site with stagnant water in the drainage canals – source of water for the people but also breeding grounds for mosquitoes
Methods

The study site:

- Arid/semi-arid region in northeastern Kenya
- Two irrigation schemes and pastoral areas around them
- Studies:
  - Ecological/GIS analyses – secondary data
  - Entomological surveys
  - Sero-epidemiological surveys in livestock and people
Ecological analyses: Land cover changes between 1975 and 2010

Legend
- Closed trees
- Open trees (65-40% crown cover)
- Very open trees (40-15% crown cover)
- Trees and shrubs savannah
- Open trees on temporarily flooded land
- Open shrubs (65-40% crown cover)
- Very open shrubs (40-15% crown cover)
- Closed herbaceous vegetation on permanently flooded land
- Open to closed herbaceous vegetation on temporarily flooded
- Open to closed herbaceous vegetation
- Irrigated land / Cropland
- Tana River-Waterbodies
- Clouds
- Urban and Rural Settlemens

20 0 20 40 60 80 Kilometers

1975 b) 2010
Field surveys

- Mosquito sampling
- Livestock and human sampling
  - Sample size determination
  - Serum samples analyzed using various ELISA kits

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Samples used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rift Valley fever virus, <em>Brucella</em> spp., and <em>Coxiella burnetii</em></td>
<td>Livestock and people</td>
</tr>
<tr>
<td>West Nile virus, dengue fever virus, <em>Leptospira</em> spp.</td>
<td>People</td>
</tr>
</tbody>
</table>
Data analysis

- Ecosystem changes – GIS analysis to determine habitat rarity
- Entomology and sero-prevalence data
  - Treated as point-referenced data
  - Analyzed using stochastic partial differential equation implemented in R INLA (Rue et al., 2009)
  - Significance of the spatial effect -- DIC

Triangulation in R INLA to capture spatial effects
Results: Apparent densities of mosquitoes trapped
### Outputs of a regression model used to analyse the effects of rainfall and irrigation on mosquito densities

<table>
<thead>
<tr>
<th>Variable</th>
<th>Levels</th>
<th>All mosquitoes trapped</th>
<th>Primary RVF vectors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Credible interval</td>
<td>Credible interval</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.50% 97.50%</td>
<td>2.50% 97.50%</td>
</tr>
<tr>
<td>Land use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>1.23</td>
<td>0.38</td>
<td>1.47</td>
</tr>
<tr>
<td>Other</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Rain</td>
<td>0.03</td>
<td>0.00</td>
<td>0.03</td>
</tr>
<tr>
<td>Hyper-parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theta 1</td>
<td>-3.03</td>
<td>1.97</td>
<td>-3.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-6.79</td>
<td>-9.75</td>
</tr>
<tr>
<td>Theta 2</td>
<td>1.87</td>
<td>1.53</td>
<td>2.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-1.23</td>
<td>-3.95</td>
</tr>
<tr>
<td>DIC</td>
<td></td>
<td>1099.57</td>
<td>641.39</td>
</tr>
</tbody>
</table>

DIC (Deviance Information Criterion): A measure of model fit, lower values indicating better fit.
Posterior distributions of irrigation and rainfall parameters from the mosquito regression model
Sero-prevalences of target pathogens in livestock

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Sero-prevalence (95% CI)</th>
<th>Irrigated areas</th>
<th>Non-irrigated areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rift Valley fever</td>
<td>22.2 (20.1 – 24.4)</td>
<td></td>
<td>36.0 (31.7 – 40.5)</td>
</tr>
<tr>
<td>Coxiella burnetti</td>
<td>14.5 (13.1 – 16.0)</td>
<td></td>
<td>9.5 (7.2 – 12.2)</td>
</tr>
<tr>
<td>Brucella spp</td>
<td>2.8 (2.0 – 3.7)</td>
<td></td>
<td>5.3 (3.4 – 7.7)</td>
</tr>
</tbody>
</table>

Posterior distribution of the land use parameter
Odd ratios from a regression model used to analyse sero-prevalences of the zoonotic pathogens in people

- Odds of being exposed in an irrigated area compared to pastoral

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVF</td>
<td>1.27</td>
</tr>
<tr>
<td>WNV/Dengue</td>
<td>1.27</td>
</tr>
<tr>
<td>C. burnetti</td>
<td>1.13</td>
</tr>
<tr>
<td>Leptospira spp</td>
<td>0.38</td>
</tr>
<tr>
<td>Brucella spp</td>
<td>0.21</td>
</tr>
</tbody>
</table>
Discussion and conclusions

• Irrigation – increased food production at the expense of habitat fragmentation, biodiversity conservation

• Used multiple pathogens to generate generic lessons

• Irrigation and primary vectors of RVF

• Biodiversity and disease regulation/dilution effect --- inconsistent findings
  o Results from livestock – no significant patterns – movement across areas
  o Results from people – higher risk of vector-borne diseases in irrigated area and directly transmitted zoonoses in pastoral area
Acknowledgements

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