A continental risk map of human African trypanosomiasis

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Rationale

- Continental estimates of people at risk of HAT were last provided by a WHO Expert Committee held in 1995.
- These estimates need to be updated because:
  - they were largely based on expert opinion and educated guess;
  - HAT epidemiological situation has changed substantially since 1995.
- Data assembled in the framework of the Atlas of HAT initiative, as well as GIS datasets and tools, now enable up-to-date, evidence-based estimates to be developed.
Materials

- Input data
  - Reporting period 2000-2009
  - Reported cases of *Trypanosoma brucei gambiense* (170,492) and *T. b. rhodesiense* infection (5,084)
    - Source: the Atlas of HAT
    - HAT cases geo-referenced at the village level
    - average geo-referencing accuracy: ≈ 1,000 m
  - human population
    - Source: Landscan™
    - resolution ~ 1 km
Methods

• Definition of HAT relative risk (R):
  – \( R = \frac{D}{P} \), where
    • \( D \) = average annual disease intensity
    • \( P \) = average annual population intensity
  – intensity is the mean number of ‘events’ per unit area
    (i.e. number of HAT cases per \( km^2 \) and number of people per \( km^2 \))

• Intensity surfaces \( D \) and \( P \) are estimated through ‘spatial smoothing’ (kernel density)
Spatial smoothing

• Used in epidemiology to facilitate analysis of point data
• We used a “quadratic kernel” as smoothing function:

$$\hat{\lambda}_\tau(s) = \sum_{i=1}^{n} \frac{1}{\tau^2} k\left(\frac{s - s_i}{\tau}\right)$$

• $\tau$ is referred to as the “bandwidth” or “search radius”
  – the higher $\tau$, the smoother the intensity surface
  – we used $\tau = 30$ km
Kernel-smoothing for 1 HAT case
The risk of HAT Kernel-smoothing: HAT cases in Chad and Central African Republic.
# Categories of risk

<table>
<thead>
<tr>
<th>Category</th>
<th>$R = D / P$</th>
<th>HAT cases per annum</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>$R &gt; 10^{-2}$</td>
<td>$\geq 1$ per $10^2$ people</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>$10^{-3} &lt; R &lt; 10^{-2}$</td>
<td>$\geq 1$ per $10^3$ people AND $&lt; 1$ per $10^2$ people</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>$10^{-4} &lt; R &lt; 10^{-3}$</td>
<td>$\geq 1$ per $10^4$ people AND $&lt; 1$ per $10^3$ people</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>$10^{-5} &lt; R &lt; 10^{-4}$</td>
<td>$\geq 1$ per $10^5$ people AND $&lt; 1$ per $10^4$ people</td>
<td></td>
</tr>
<tr>
<td>Very low</td>
<td>$10^{-6} &lt; R &lt; 10^{-5}$</td>
<td>$\geq 1$ per $10^6$ people AND $&lt; 1$ per $10^5$ people</td>
<td></td>
</tr>
<tr>
<td>Marginal</td>
<td>$R &lt; 10^{-6}$</td>
<td>$&lt; 1$ per $10^6$ people</td>
<td></td>
</tr>
</tbody>
</table>
Results – Regional maps

Risk of *T. b. gambiense* infection
[No. cases/inhabitants/year]

- Very high  \( \geq 1/10^6 \)
- High  \(< 1/10^6 \) to \( \geq 1/10^5 \)
- Moderate  \(< 1/10^5 \) to \( \geq 1/10^4 \)
- Low  \(< 1/10^4 \) to \( \geq 1/10^3 \)
- Very low  \(< 1/10^3 \) to \( \geq 1/10^2 \)

Lambert Azimuthal Equal Area Projection

Kilometres 0 200 400 600 800
The risk of HAT in Central Africa is illustrated on this map, showing the varying levels of risk across different regions.
The risk of HAT

Optimized for printing in A3 format

Focus - level risk maps
Human African trypanosomiasis

Mapping the risk of human African trypanosomiasis

Based on information on the HAT reported cases and the geographic distribution of human population, spatially explicit estimates of population at risk have been calculated and classified in five categories of risk, ranging from "very high" to "very low". Approximately 70 million people are estimated to be at different levels of risk of contracting HAT in Africa.

Instructions
Click on the country you are interested to go to the map of the country showing the areas and the population at risk of HAT. Click on the name of the focus you are interested to get the zoomed map of risk of HAT.

- Angola: (in process)
- Benin: No cases reported during the period 2000-2009
- Botswana: No cases reported during the period 2000-2009
- Burkina Faso: No cases reported during the period 2000-2009
- Burundi

- Cameroon: Mambé, Fortem, Campo, Bipindi, Doumé, Bafia - Mbendjok
- Central African Republic: Batangafo, Haut Mbomou, Lobaye, Matikoulo, Mbk, Nola, Obo, Oumari, Zemio - Djemal
- Chad: Southern, Bodo, Gouré, Moïsa
- Congo: Mossaka, Cuvette Ouest, Gamboma, Mpouya Makotipoko Ngabé, Igrié, Mouyondzi, Mpouya - Makotipoko - Ngabé, Mbandingou, Mindouli - Mfouti, Loudima - Nkayi
- Côte d'Ivoire: Bonor, Daloa, Fromager, Moyen Cavally, Oumé, Vavoua, Sinfra, Aboisso
- Democratic Republic of the Congo: in process
- Ethiopia: No cases reported during the period 2000-2009
- Equatorial Guinea: Muni, Luba, Kong, Campo
## Population at risk (*T. b. gambiense*)

<table>
<thead>
<tr>
<th>Country</th>
<th>Total country population (no. persons × 10³)</th>
<th>Population at risk (no. persons × 10³)</th>
<th>Very High</th>
<th>High</th>
<th>Moderate</th>
<th>Low</th>
<th>Very Low</th>
<th>Total at risk</th>
<th>% of total country population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>12,799</td>
<td></td>
<td>740</td>
<td>749</td>
<td>3,049</td>
<td>229</td>
<td>4,767</td>
<td></td>
<td>37.2</td>
</tr>
<tr>
<td>Cameroon</td>
<td>18,879</td>
<td></td>
<td>-</td>
<td>-</td>
<td>28</td>
<td>238</td>
<td>365</td>
<td>631</td>
<td>3.3</td>
</tr>
<tr>
<td>Central African Republic</td>
<td>4,511</td>
<td></td>
<td>28</td>
<td>41</td>
<td>130</td>
<td>138</td>
<td>99</td>
<td>435</td>
<td>9.6</td>
</tr>
<tr>
<td>Chad</td>
<td>10,329</td>
<td></td>
<td>-</td>
<td>109</td>
<td>114</td>
<td>120</td>
<td>123</td>
<td>465</td>
<td>4.5</td>
</tr>
<tr>
<td>Congo</td>
<td>4,013</td>
<td></td>
<td>4</td>
<td>109</td>
<td>451</td>
<td>1,825</td>
<td>177</td>
<td>2,566</td>
<td>63.9</td>
</tr>
<tr>
<td>Côte d’Ivoire</td>
<td>20,617</td>
<td></td>
<td>-</td>
<td>-</td>
<td>230</td>
<td>722</td>
<td>1,720</td>
<td>2,672</td>
<td>13.0</td>
</tr>
<tr>
<td>Democratic Republic of the Congo</td>
<td>68,693</td>
<td></td>
<td>23</td>
<td>3,546</td>
<td>10,767</td>
<td>15,674</td>
<td>6,237</td>
<td>36,247</td>
<td>52.8</td>
</tr>
<tr>
<td>Equatorial Guinea</td>
<td>633</td>
<td></td>
<td>-</td>
<td>2</td>
<td>27</td>
<td>8</td>
<td>6</td>
<td>43</td>
<td>6.8</td>
</tr>
<tr>
<td>Gabon</td>
<td>1,515</td>
<td></td>
<td>-</td>
<td>2</td>
<td>21</td>
<td>19</td>
<td>761</td>
<td>803</td>
<td>53.0</td>
</tr>
<tr>
<td>Guinea</td>
<td>10,058</td>
<td></td>
<td>-</td>
<td>-</td>
<td>187</td>
<td>488</td>
<td>1,932</td>
<td>2,606</td>
<td>25.9</td>
</tr>
<tr>
<td>Nigeria</td>
<td>149,229</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>368</td>
<td>1,814</td>
<td>2,183</td>
<td>1.5</td>
</tr>
<tr>
<td>Sierra Leone</td>
<td>5,132</td>
<td></td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>83</td>
<td>87</td>
<td>170</td>
<td>3.3</td>
</tr>
<tr>
<td>South Sudan</td>
<td>6,996</td>
<td></td>
<td>15</td>
<td>401</td>
<td>453</td>
<td>334</td>
<td>67</td>
<td>1,270</td>
<td>18.2</td>
</tr>
<tr>
<td>Uganda</td>
<td>32,370</td>
<td></td>
<td>-</td>
<td>142</td>
<td>1,275</td>
<td>456</td>
<td>251</td>
<td>2,124</td>
<td>6.6</td>
</tr>
<tr>
<td>Other Endemic Countries*</td>
<td>103,673</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>449,447</strong></td>
<td></td>
<td><strong>70</strong></td>
<td><strong>5,092</strong></td>
<td><strong>14,431</strong></td>
<td><strong>23,521</strong></td>
<td><strong>13,869</strong></td>
<td><strong>56,983</strong></td>
<td><strong>12.7</strong></td>
</tr>
</tbody>
</table>

# Population at risk (*T. b. rhodesiense*)

*Countries at marginal risk: Botswana, Ethiopia, Namibia, Rwanda and Swaziland.*

<table>
<thead>
<tr>
<th>Country</th>
<th>Total country population (no. persons × 10^3)</th>
<th>Risk (no. persons × 10^3)</th>
<th>% of total country population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Very High</td>
<td>High</td>
</tr>
<tr>
<td>Burundi</td>
<td>9,511</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Kenya</td>
<td>39,003</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Malawi</td>
<td>15,029</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mozambique</td>
<td>21,669</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>United Republic of Tanzania</td>
<td>41,049</td>
<td>-</td>
<td>22</td>
</tr>
<tr>
<td>Uganda</td>
<td>32,370</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Zambia</td>
<td>11,863</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>11,393</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other Endemic Countries*</td>
<td>101,420</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>283,306</td>
<td>-</td>
<td>22</td>
</tr>
</tbody>
</table>
Discussion

• Because of the methodological differences, it is unwarranted to make comparisons with previous figures for HAT at-risk population, especially if the goal is to capture trends.
• No attempt was made to account for under-detection and under-reporting, and work is ongoing to address this aspect.
• The input data and the resulting risk maps are based on places of residence, which do not necessarily correspond to the places of contact between people and infected tsetse flies.
Conclusions

• The methodology and risk estimates here presented were endorsed by
  – a WHO meeting of NSSCPs Coordinators and other stakeholders (December 2012)
  – a WHO Expert Committee held in Geneva (April 2013)

• There is consensus that the presented risk maps and future updates thereof will provide indicators to monitor the progress in HAT control and elimination
Acknowledgments

• NSSCPs of HAT-endemic countries, NGOs and Research Institutes, which provided the input data.
• Sanofi, which provided financial support to WHO through a Public-Private partnership
• This work is the result of a WHO/FAO collaboration in the framework of the Programme Against African Trypanosomosis (PAAT)
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  – International Fund for Agricultural Development (IFAD)
    • Project “Pro-poor Integrated Packages to Enhance Policy and Decision Making against the African Animal Disease Burden in sub-Saharan Africa” (GCP/RAF/442/IFA)
  – Italian Government - Italian Contribution to the FAO Trust Fund for Food Security and Food Safety
    • Project “Improving food security in sub-Saharan Africa by supporting the progressive reduction of tsetse-transmitted trypanosomosis in the framework of the NEPAD” (GTFS/RAF/474/ITA)
References
