Cholera is an acute intestinal infection caused by ingestion of food or water contaminated with the bacterium, *Vibrio cholerae*. It has a short incubation period, from one to five days, and produces an enterotoxin that causes a copious, painless, watery diarrhea that can lead to severe dehydration and death if treatment is not promptly given. In 2015, there was an outbreak of cholera in Iraq. The WHO released three notices (dated 26 November 2015, 12 October 2015, and 28 September 2015). The total number of affected persons with laboratory-confirmed cholera was 4,592, with only 2 deaths. The outbreak was likely exacerbated by a few factors, including climate, shifting rain and drought patterns thus spreading waterborne cholera, and by conflict throughout the Middle East, which includes the existences of vast un-governed regions, and a refugee crisis.

Limited resources could better be directed to prevent outbreaks if it were possible to assess the risk of an outbreak spatially. This project seeks to investigate health risk for cholera by identifying favorable physical, social, and economic preconditions for cholera outbreaks. The model is based on the assumption that endemic reservoirs of cholera occur and that environmental conditions exacerbate the spread of cholera. If the environmental preconditions are met, the subsequent spread of cholera depends mainly on socio-economic factors such as population density and access to safe water supply. This project focuses on the environmental preconditions, security factors, and socio-economic vulnerability factors that may predict the risk of cholera outbreak risk potential.

### SPATIAL QUESTIONS

1. Where did environmental factors, security risk, and socio-economic vulnerability shape the 2015 cholera outbreak in Iraq?

2. What areas of Iraq have the highest risk for cholera outbreak?

### ENVIRONMENTAL RISK

Data Collection & Cleaning: Data was downloaded and imported into ArcMap. Previous cholera was not available as a shapefile. World Health Organization reports of province-level cholera data was imported as a rank to the administrative boundary level. Security, IDP, and hospitals were latitude/longitude points converted to XY coordinates. Hospital data had missing latitude and longitude data points that were manually entered. Raster datasets were resampled to 874.8 x 874.8 pixel size. ArcGIS Analysis: Rainfall, surface temperature, elevation and population density were reclassified to reflect specific ranges of risk. Euclidean distance to water bodies was calculated, then reclassified to reflect distance further to water as an increase in risk. Kernel density of terrorist events, internally displaced persons, and proximity to hospitals was analyzed, then reclassified so that proximity to the events indicated certain risk of cholera outbreak.

### SECURITY RISK

### VULNERABILITY

Population At Risk Calculation: The highest risk (dark red) areas were identified via reclassification and tied to the population density, using zonal statistics.

### DISCUSSION

#### LEFT

The 2015 outbreak witnessed a cumulative total of 4,592 cases (orange line) throughout the year. The epidemic curve shows that 2015/09 and 2015/10 experienced the highest rate of new cholera cases (blue bar graphs).

#### RIGHT

The central and southeast portion of Iraq has the highest risk of cholera outbreak, based on the combination of environmental, security, and vulnerability factors. This darkest red, or highest risk, regions include some of the most populated regions of Iraq.

#### BELOW

Population at risk per province was calculated based on the number of individuals who were located in the highest risk category (dark red). The total population of Iraq that is at high risk of outbreak is 14,766,966. The total Iraqi population is 36.3 million, so the high-risk population for cholera outbreak represent 40.68% of the entire population. The provinces Qadissiya, Thi-Qar, and Baghdad, in the central and southeast region of Iraq, have the highest population at risk.

### METHODS

#### POPULATION AT RISK

<table>
<thead>
<tr>
<th>Province</th>
<th>Population At Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qadissiya</td>
<td>722,820</td>
</tr>
<tr>
<td>Thi-Qar</td>
<td>626,875</td>
</tr>
<tr>
<td>Baghdad</td>
<td>619,245</td>
</tr>
<tr>
<td>Najaf</td>
<td>555,391</td>
</tr>
<tr>
<td>Wassit</td>
<td>490,931</td>
</tr>
<tr>
<td>Kerbala</td>
<td>407,349</td>
</tr>
<tr>
<td>Muthana</td>
<td>359,948</td>
</tr>
<tr>
<td>Missan</td>
<td>256,389</td>
</tr>
<tr>
<td>Basrah</td>
<td>136,726</td>
</tr>
<tr>
<td>Babylon</td>
<td>114,026</td>
</tr>
</tbody>
</table>

#### DATA SOURCES

1. Rainfall: National Aeronautics and Space Administration (NASA) GOES wide swath precipitation estimates, average for March through October 2015.
2. Surface Temperature: National Aeronautics and Space Administration (NASA)/Land Process Distributed Active Archive Center (LP-DAC) MODIS Terra Land Surface Temperature and Emissivity Monthly and GCC (Goddard Earth Carbon Center, monthly average for March through October 2015.
3. Elevation: Center for Global Land Use and Research (CGLUR), World Digital Elevation Data, and data.
5. Tectonic Events: University of Maryland/USGS Global Tectonic Database (GTDB) Tectonic events, 2014 data.
7. Cholera Outbreak: World Health Organization (WHO) Press Releases. The WHO press releases list the number of new cholera cases by provinces on September 14, 2015, October 13, 2015, November 21, 2015, and December 15, 2015. Cases were manually entered into provincial level population.
9. Methodological Description: The Fletcher School, Tufts University.

Cartographer: Elyse Gatt
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Course: DHR-P307 GIS for Intl Applications Project: WGI 1994 UTM Zone 38N