Modeling global, urban, and rural exposure to climate-related hazards

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Climate-Related Hazards: A Method for Global Assessment of Urban and Rural Population Exposure to Cyclones, Droughts, and Floods

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Objectives

1. Estimate and rank relative population exposure of countries to the climate-related hazard events of cyclone, drought, and flood

   **Relative Population Exposure**: the likelihood that a person in a location would be exposed to a given hazard event in a given period of time

2. Differentiate urban and rural areas

3. Automate global, urban, and rural exposure estimates using ArcGIS Model Builder
CHRR Global Cyclone Frequency and Distribution

Source: Center for Hazards and Risk Research (CHRR)
www.ldeo.columbia.edu/chrr/research/hotspots/coredata.html
CHRR Global Drought Frequency and Distribution

Source: Center for Hazards and Risk Research (CHRR)
www.ldeo.columbia.edu/chrr/research/hotspots/coredata.html
CHRR Global Flood Frequency and Distribution

Source: Center for Hazards and Risk Research (CHRR)
www.ldeo.columbia.edu/chrr/research/hotspots/coredata.html
LandScan 2008 Global Population Density

Source: www.web.ornl.gov/sci/landscan
Model Builder: Country-level data
CHRR Data - Thailand
LandScan Data - Thailand

Ancillary data used:
- Administrative boundaries
- Census Information
- Land cover
- Elevation, slope
- Roads
- Satellite imagery
Urban

Greater access to health care
Reliance on cash income
Congested evacuation routes

Rural

Increased community/social structure and network
Decreased access to services, the market, transportation
Reliance on subsistence agriculture

Sources:
Differentiating Urban-Rural

Remote Sensing Methods
- Night-time lights
- Land cover
- Satellite imagery

Ground Input Methods
- Census information
- Modeled population

Differentiating Urban-Rural

Ground Input Methods
- Census information
- Modeled population

Strengths
- Allows degrees of “urban-ness” to be calculated
- Incorporates multiple facets of urban definition
- Built infrastructure, population size/density

Weaknesses
- Dependent on input population dataset
- Spatial resolution
- Modeled population method

Defining a Population Threshold

United Nations World Urbanization Prospects
- country-specific estimates for proportion rural

**Thailand Example:**
- UN estimated proportion: 66% Rural
- Total LandScan population = 78,668,490

\[
\%_{\text{Rural}} = \frac{\sum \text{(Value } \times \text{ Count)}}{\text{Total Population}}
\]

Vary LandScan population density threshold until % Rural matches the UN estimated proportion
Population Density
(VALUE) Range:
0 - 5
Population Threshold:
0.2% Rural

Sorted population density values

<table>
<thead>
<tr>
<th>VALUE</th>
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<th>POP</th>
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<tr>
<td>14</td>
<td>5259</td>
<td>73626</td>
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</table>
Population Density (VALUE) Range:
0 - 38
Population Threshold:
5% Rural

<table>
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</tr>
<tr>
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</table>
Population Density
(VALUE) Range: 0 - 60
Population Threshold: 10% Rural
Population Density
(VALUE) Range:
0 - 394
Population Threshold:
30% Rural

<table>
<thead>
<tr>
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<th>POP</th>
</tr>
</thead>
<tbody>
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<tr>
<td>402</td>
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<td>12060</td>
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</table>
Population Density
(VALUE) Range:
0 - 2471
Population Threshold:
66% Rural
Model Builder: Raster Reclassification

- Python script identifies each country's population density threshold and creates Reclass Table.
- Model Builder: Iterative “Reclass by Table”
Urban-Rural Reclassification

Reclassify Table

<table>
<thead>
<tr>
<th>from_value</th>
<th>to_value</th>
<th>reclass_value</th>
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</thead>
<tbody>
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<td>1</td>
</tr>
<tr>
<td>2472</td>
<td>5834</td>
<td>2</td>
</tr>
</tbody>
</table>

Rural

Urban

Reclass by Table

- Input raster: THA Case Study - gpw\tha_pds
- Input remap table: C:\Users\Elizabeth\Documents\My Research\Water Institute W
- From value field: from_value
- To value field: to_value
- Output value field: reclass_value

Output raster: C:\Users\Elizabeth\Documents\tha_pds.ur

Change missing values to NoData (optional)
Cell Exposure Calculation

\[
\text{Cell Exposure}_{\text{Hazard}} = \text{Population}_{\text{cell}} \times H_{\text{Hazard,cell}}
\]

- Cyclone Exposure
- Drought Exposure
- Flood Exposure

H is the hazard event likelihood.
Urban, Rural, or Country Exposure

Average Population Exposure\sub{Area} = \frac{\sum Population_{cell} \times H_{Hazard,cell}}{Pop_{Area}}

\sum Cell Exposure_{Area} = \frac{\sum Cell Exposure_{Area}}{Pop_{Area}}

Area - Urban, Rural, or Entire Country
Model Builder: Urban, Rural Exposure
Urban, Rural Exposure
Urban, Rural Drought (CHRR)
Average Urban Population Exposure to Drought

\[ \sum \quad \times \quad \]

\[ \text{Population}_{\text{cell}} \quad \times \quad \text{H}_{\text{Drought,cell}} \]

Total Urban Population

Selected Urban Area
Average Rural Population Exposure to Drought

\[
\sum \left( \text{Population}_{cell} \times H_{\text{Drought,cell}} \right)
\]

Total Rural Population
Average Country Population Exposure to Drought

\[ \sum_{Population_{cell}} \times \sum_{H_{Drought,cell}} + \sum_{Population_{cell}} \times H_{Drought,cell} \]

Total Thailand Population
Average Cyclone Population Exposure
Average Drought Population Exposure
Average Flood Population Exposure
Limitations

- Hazard data is dependent on reported hazards
- Relative hazard frequency limited by ~20 year recording period
- Population data is modeled and uncertainty is dependent on resolution and age of census data
- Urban-rural binary definition
Next Steps

- Apply climate-related average population exposure results to specific vulnerabilities such as loss of drinking water
- Downscaling country-level exposure to regional models
  - Use higher resolution hazard data to validate whether differences in urban and rural exposure hold true at different spatial scales
- Urban-Rural gradient; identification of slums
References


Thank you –
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Questions?
Global Urban, Rural Average Exposure

- 40% higher global average exposure to cyclones for urban compared to rural
  - Cities and cyclones on coastlines
- 34% lower global average exposure to droughts for urban compared to rural
- No difference in global average exposure to flood
  - Many causes of floods (river vs. storm surge vs. snowmelt)