
– Brownfield development
Spatial Patterns of Pb Hotspots

- Sources of Pb:
  - Traffic (lead additive in gas)
  - Burning of peat & coal for home heating
  - Solid waste
- Spatial cluster (regional hotspots) – sites with high Pb concentration surrounded by high concentration sites.
- Spatial outlier (individual hotspots) – sites with high Pb concentration surrounded by low concentration sites.
- Cool spots
Data

- 166 surface soil samples (0-10 cm depth)
- Stratified random sampling (1 sample per 0.25 km$^2$)

One-point Descriptor

<p>| Table 1 – Comparison between Pb concentrations in soils of Galway City and Ireland (in mg/kg) |
|-------------------------------------------------|---------------------------------|</p>
<table>
<thead>
<tr>
<th>N</th>
<th>Min.</th>
<th>5%</th>
<th>10%</th>
<th>25%</th>
<th>Median</th>
<th>75%</th>
<th>90%</th>
<th>95%</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galway City soils*</td>
<td>166</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>42</td>
<td>58</td>
<td>86</td>
<td>132</td>
<td>187</td>
</tr>
<tr>
<td>Soils of Ireland*</td>
<td>1310</td>
<td>1.1</td>
<td>11.7</td>
<td>13.6</td>
<td>18.2</td>
<td>24.8</td>
<td>33.5</td>
<td>48.0</td>
<td>61.9</td>
</tr>
<tr>
<td>Mineral soils of Ireland*</td>
<td>977</td>
<td>4.8</td>
<td>12.4</td>
<td>14.3</td>
<td>18.0</td>
<td>24.8</td>
<td>33.3</td>
<td>47.8</td>
<td>61.0</td>
</tr>
</tbody>
</table>

*Zhang (2006); *Pry et al. (2007)
Moran’s I (Two-point Descriptor)

\[ I = \left( \frac{n}{\sum_i \sum_j w_{ij}} \right) \left( \frac{\sum_i \sum_j w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2} \right) \]

\( x_i \) and \( x_j \): values observed at locations \( i \) and \( j \)
\( \bar{x} \): average of all \( x_i \)
\( w_{ij} \): weight between locations \( i \) and \( j \)

Examples of \( w_{ij} \)

\( w_{ij} = 1 / d_{ij} \)
\( w_{ij} = 1 \) if \( i \) touches \( j \), else 0 (local Moran’s I)

+1: clustering (positive spatial autocorrelation)
0: random
-1: dispersion (negative spatial autocorrelation)

Conceptualization of Spatial Relationships

Specifies how spatial relationships between features are conceptualized.

- Inverse Distance—The impact of one feature on another feature decreases with distance.
- Inverse Distance Squared—Same as Inverse Distance, but the impact decreases more sharply over distance.
- Fixed Distance Band—Everything within a specified critical distance is included in the analysis; everything outside the critical distance is excluded.
- Zone of Indifference—A combination of Inverse Distance and Fixed Distance Band. Anything up to a critical distance has an impact on your analysis. Once that critical distance is exceeded, the level of impact quickly drops off.
- Polygon Contiguity (First Order)—The neighbors of each feature are only those with which the feature shares a boundary. All other features have no influence.
- Get Spatial Weights From File—Spatial relationships are defined in a spatial weights file. The pathname to the spatial weights file is specified in the Weights Matrix File parameter.

Value of Distance Band: 
> sampling interval
< half of the smaller dimension of the study area
What can you tell about the difference in these patterns?

A

B

C

I = 0

I = 0.06

I = -0.04

Test for Statistical Significance

• T-test (observed data have a normal distribution)
  – Z score, p value ($\alpha$)
• (Conditional) permutation
  – Rearrangement of existent elements
  – Check for pseudo significance
    $$PS = \frac{(M+1)}{(R+1)} \times 100\%$$
    $M$: number of instances that meet certain criteria
    $R$: total number of permutation instances
A. Random Pattern

Global Moran's I Summary
Moran's Index: 0.000019
Z Score: 0.987484
p-value: 0.323405

B. Positive Spatial Autocorrelation

Global Moran's I Summary
Moran's Index: 0.057173
Z Score: 6.564235
p-value: 0.000000
C. Negative Spatial Autocorrelation

Global Moran's I Summary
Moran's Index: -0.036682
Z Score: -2.593673
p-value: 0.009496

Local Moran's I:
Local Indicators of Spatial Association (LISA)
Transform Data to Normal Distribution

- Box-Cox (Power/Log) Transformation (see eq. 2)
- Normal score transformations (see page 214)

Results – Distance Bands

- 1000 m
- 5000 m
- 2000 m
Results – Data Transformation

<table>
<thead>
<tr>
<th>Original</th>
<th>Normal Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box-Cox</td>
<td></td>
</tr>
</tbody>
</table>

Results – Outliers

- Not recommended to remove outliers
- Instead, replace their values with the upper bound of the Box-and-Whiskers plot.
Conclusions

- Conceptualization of spatial relationship and the distribution (i.e., histogram) of data affect the results of LISA
- Provide information for spatial interpolation

Moran’s scatterplot (available in Geoda)
- X axis: variable value at a location
- Y axis: spatial weighted average variable values of the neighbors of that location.