The goal of this study is to analyse the vulnerability and potential risk on urban heat island (UHI) through Local Climate Zones (LCZ) as an indicator of exposure to heat. Sensitivity is associated an indicator based on demography and age. The cartography of these indicators over the region allows to characterize the most vulnerable areas with a major resolution than all the works made until now in Barcelona.

**Study design**

1. Characterize UHI in Barcelona
2. Map the study area into LCZ
3. Analyze the vulnerability through the heat vulnerability indexes (HV1)
4. Evaluate the potential risk (UHI + HV1)

### 2- Mapping the study area

<table>
<thead>
<tr>
<th>Layer</th>
<th>Information</th>
<th>GSD</th>
<th>Year</th>
<th>Format</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Atlas</td>
<td>Topography of urban fabric</td>
<td>50m</td>
<td>2012</td>
<td>Vector</td>
<td>LCZ map</td>
</tr>
<tr>
<td>LCZ Cat</td>
<td>24 categories of land cover</td>
<td>0.25m</td>
<td>2010</td>
<td>Vector</td>
<td>LCZ map</td>
</tr>
<tr>
<td>Building Heights</td>
<td>Heigth (m)</td>
<td>0.5m</td>
<td>2014</td>
<td>Vector</td>
<td>LCZ map</td>
</tr>
<tr>
<td>Othophoto</td>
<td>Mosaic of aerial photos</td>
<td>0.25m</td>
<td>2016</td>
<td>Raster</td>
<td>Validade</td>
</tr>
<tr>
<td>Population</td>
<td>Population by age</td>
<td>100m</td>
<td>2016</td>
<td>Vector</td>
<td>Validade</td>
</tr>
</tbody>
</table>

Table 1. Material and data used to create LCZ maps.

**Barcelona Metropolitan Area**

- **Raster approach**
- **Digital Elevation Model**
- **Building footprint layer**
- **Tree cover layer**
- **Building heights**
- **Water bodies - non-potable**
- **Vegetation layer**
- **Urban Fabrics**
- **Building Fabric Categories**

**Barcelona (vector approach)**

- **Mosaic of aerial photos**
- **LCZ map**
- **UHIs - current and historical**
- **Area of interest**

![Fig 2. Workflow process of GIS – LCZ map.](image)

**3- Vulnerability heat indexes**

**Vulnerability to UHI**

- Exposure to heat: Local Climate Zones (A)
- Sensitivity – demography – age (B)

**Indexes to evaluate the vulnerability to UHI:**

**A) Urban Climate Vulnerability Index (UCVI)**

\[
UCVI = \frac{LCZ_i}{\max(LCZ)} \times 100
\]

**B) Climate Vulnerability People (CVP)**

\[
CVP = \frac{P_{male} + P_{female}}{P_{total}} \times 100
\]

**COUPLING UCVI + CVP:**

- Explorative data analysis (EDA)
- K-means cluster analysis
- Thresholds based on extremes

**4- Evaluate potential risk**

![Fig 3. LCZ – GIS raster map 100x100m of Barcelona Metropolitan Area, input for UrbClim Model.](image)

**Barcelona Metropolitan Area (raster approach)**

**Barcelona (vector approach)**

**1- UHI in Barcelona**

In order to characterize the hazard, we perform a classic analysis comparing the daily Trmin between an urban weather station (1) and a peri-urban weather station (2) (fig 10/11) in Barcelona over a 7 years period (2008-2015). To classify the level of hazard of UHI a normal distribution has been applied to this differences of temperatures. Afterwards, has been combined with vulnerability scenarios to obtain a matrix of risk (table 2).

![Fig 4. LCZ – GIS vector map of Barcelona with a multisolution (2x2m to 9x9m) to estimate the vulnerability at high resolution.](image)

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**Table 2. Matrix of potential risk maps coupling hazard characterization and vulnerability scenarios.**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>A</td>
<td>B</td>
<td>A1</td>
<td>A2</td>
</tr>
</tbody>
</table>

**Fig 11. UHIs corresponding to the difference between each pixel (100x100m) and 2. From JJA, Tmax P95 (2010-2016), ERAS – Run with UrbClim Model (output).**

**Fig 12. Map of potential risk for the percentile 95 of JJA UHI (2010-2016).**

**Fig 13. Map of potential risk for the percentile 95 of JJA UHI (2010-2016).**

**Fig 14. Map of potential risk for the percentile 95 of JJA UHI (2010-2016).**