Monitoring Urbanization in Latin American Metropolitan Areas (Bogota, Quito and Lima)

Elke Krätzschmar, Rainer Malmberg
Industrieanlagen Beriebsgesellschaft mbH, Germany
Background: The Project

Monitoring Urbanization in Latin American Metropolitan Areas
... a project focusing on preparation of demonstration cases for Urban Mapping

within the context of

financed by ESA
(ESRIN/AO/1-7663/13/I-AM)

key users

Service design, preparation & analysis
Main objectives:

- Development of a **time & cost efficient** process for urban structure analysis
- The **capability of Earth Observation** as suitable basis for baseline mapping, urban planning and monitoring
- Establish standard procedure to create **comparable results on a global level** (*Urban Atlas* classification)
- **Historical analysis** of urban sprawl in order to derive urban growth patterns.
- Detection of potential hotspots for **urban risks**
Urban Atlas - Logic of 6 different housing classes

Advantages

- Different fabric often represent different characteristics of living/use fragmentation
- Different density separates areas of similar fabric
- Identifying urban density is a fast & cost effective way of identifying mixed areas without footprint allocation
- Density of housing can be analysed according to its change over time
- Combination of Fabric + Density allows estimation of population (other input: known absolute numbers or spatial resolution of income or …)
- It works all over the World

Limitation

- Formal/Informal structures relate to image texture (small features, often crowded)
Urban Atlas - Logic of 6 different housing classes

Bogota

Continuous dense urban fabric

Continuous medium dense urban fabric

Discontinuous dense urban fabric

Source: SPOT6, ESRI Basemap; Google street view
Urban Atlas - Logic of 6 different housing classes
Bogota

Discontinuous medium dense urban fabric

Discontinuous sparse urban fabric

Informal settlement

Source: ESRI Basemap; Google street view
Urban Atlas - Logic of 6 different housing classes

Bogota
Urban Atlas - Logic of 6 different housing classes

Quito
Urban Atlas - Logic of 6 different housing classes

Quito
**Transportation network 2013**
- fast transit road, Other road; Railroad
- all roads wider 10m (buffering in 3m intervals)

**Urban Service 2013 and 2000**
- Urban Atlas Standard
  (minimum mapping unit 0.25/ 1ha)
- geometry compatible to Google Maps/ ESRI Basemap
- thematic accuracy > 96 %
  - cities Lima, Quito & Bogota: 71,800 polygons
- Backdating approach:
  (1) mapping 2013; (2) mapping 2000 (considering 2013)
- 18 urban classes, 5 other classes
Transportation network 2013
- fast transit road, Other road; Railroad
- all roads wider 10m (buffering in 3m intervals)

Urban Service 2013 and 2000
- Urban Atlas Standard
  (minimum mapping unit 0.25/ 1ha)

⇒ Urban Change Layer
- detailed change types
- grouped into main change characteristics
Urban Services

Transportation network 2013
- fast transit road, Other road; Railroad
- all roads wider 10m (buffering in 3m intervals)

Urban Service 2013 and 2000
- Urban Atlas Standard
  (minimum mapping unit 0,25/1ha)

→ Urban Change Layer
- detailed change types
- grouped into main change characteristics

Urban Vegetation Layer 2013
- low and high vegetation
- minimum mapping unit 0,1ha
- significant single trees

Terrain Analysis
- considering Urban Mapping Service(s)
- Risk identification, calculation of natural drainage flow...
Urban Services

contain

- Report Series
- Statistics (absolute/relative)
- Maps & Maps series (administrative units)
- Presentations
The EO Products: What They Are

- **EO data used**
  - 2000: SPOT 4/5 (2.5m ... 5m)
  - 2000: Landsat 7 (15m)
  - 2013: SPOT 5/6 (1.5 – 2.5m)
  - 2015: Sentinel 2 (10m resolution)

- **Data – easy to handle**
  - different exchange formats (shp)
  - conform to PUMA platform

- **Google-ready**
  for a wider audience (kml)
Comparability of Metropolitan regions

comparable due to

• similar dates
• similar nomenclature Urban Atlas (applied standard)
• easy to combine with other sources
• administrative units

limitations

• subset definition → often related to administrative units

• Suggestion: core area & buffer approach, considering administrative units
Lima – Urban spreading ("informal transition")
Lima – Urban spreading ("informal transition")

- detecting populated areas and open spaces in-between, density, & avg. size of housing
- fast, comparable and repeatable at reasonable quality
Urban Vegetation Layer

Connectivity & Urban Climate

protection of the Greens
Bogota – Urban Area ↔ Area with significant change
example Bogota

- urban core
  (up-to-date, draft classification)
- EOworld2 subset for mapping
  Mapping result 2013 (Urban only)
- calculation of buffer area
  (relative to absolute size of city):

\[ r(\text{buffer}) = 0,25 \sqrt{A(\text{core})} \]

+ administrative Units:

map & analyse areas under severe change

overlay with 1984
Summary: The EO Products – What They Bring

**Potential Input**
- + World Bank references
  - GIS, previous analysis layer
- + Auxiliary data
  - land use, thematic features
- + In-situ knowledge
  - hot-spots, special aspects of the cities
- + Local contact

**Context of Use?**
- providing solutions for simplification & optimization processes

**Urban Service Layer Range**

**Feedback Info (Benefits)**
- High level of detail
  - urban density classes
  - comparable (date, legend)
  - high accuracy
- Back- & up-dating
- Geographically extendable
  - Sentinel 2?
- Downstream services
  - terrain, risk ...

- Fast results
  - large area
  - low data & mapping costs: regional mapping level
  - cost aspects can be reduced by automation (reasonable quality)

- Independent
Terrain Information for urban analysis and planning
Terrain analysis (risk identification) Climate change effects

(2) http://floodlist.com/america/nasa-satellites-measure-flooding-rain-in-peru-and-bolivia
Terrain analysis (risk identification) Climate change effects

Urban Atlas 2013

- 1.1.1.1 - Continuous dense urban fabric
- 1.1.1.2 - Continuous medium dense urban fabric
- 1.1.2.1 - Discontinuous dense urban fabric
- 1.1.2.2 - Discontinuous medium dense urban fabric
- 1.1.2.3 - Discontinuous sparse urban fabric
- 1.1.2.4 - Informal transition
- 1.1.4 - Informal settlement
- 1.2.1 - Industrial and Commercial
- 1.2.1.3 - Public and Private
- 1.2.2.1 - Fast transit road
- 1.2.2.2 - Other road
- 1.2.2.3 - Railway
- 1.2.3 - Port area
- 1.2.4 - Airport
- 1.3.1 - Mineral extraction and dump site
- 1.3.3 - Construction sites
- 1.4.1 - Green urban areas
- 1.4.2 - Sports and leisure facilities
- 2.1 - Agriculture and natural vegetation
- 2.2 - Bare ground
- 3 - Forest
- 5.1 - Inland water
- 5.2 - Marine water
Terrain analysis (risk identification) Climate change effects

Slope degree

- < 5%
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 50
Automatic computation of natural drainage based on SRTM plus (30 m)

extraction of drainage lines

drainage lines and potential flooding areas
Terrain analysis (risk identification) - potential flooding zones

- Natural drainage lines
- < 1%
- < 2.5%
- < 5%
- < 10%
- < 20%
- < 25%
- < 30%
- < 40%
- Steeper
Terrain analysis (risk identification) - potential flooding zones

Potentially affected regions (2013)
Slope map suburban Lima – potential landslide areas

Slope degree

- < 5%
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 50

(slope > 30% is steep terrain), SRTM plus
Slope map suburban Lima – potential landslide areas

(slope > 30% is steep terrain), SRTM plus
Relation of geospatial and socioeconomic data

Statistic interpretation

- Link to local available socioeconomic data
  - Population density
  - Employment
  - Income situation
  - Age structure
  - Level of education
  - .......

- Benefit
  - Information of the spatial distribution of population in case of emergency response
  - Information for urban transport network planning
  - Information for planning commercial center / Industrie
  - Information for insurance sector
  - Information for planning of recreation areas in urban areas
  - Information for education sector
Population density – transporting the message

Lima, 2007

example: population density (Lima)

statistics related to absolute extent of administrative area are often not suitable/pretend a different reality

real change can only be seen related to absolute urban footprint
Population density based on Urban Mapping Service and some sort of population/commercial information (often of different kind, but can in general be transformed to suitable information for modeling)

Population estimation day-time

<table>
<thead>
<tr>
<th>Population/km²</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 500</td>
<td>Blue</td>
</tr>
<tr>
<td>&lt; 1,000</td>
<td>Light Blue</td>
</tr>
<tr>
<td>&lt; 1,500</td>
<td>Light Blue</td>
</tr>
<tr>
<td>&lt; 3,000</td>
<td>Light Blue</td>
</tr>
<tr>
<td>&lt; 5,000</td>
<td>Light Blue</td>
</tr>
<tr>
<td>&lt; 15,000</td>
<td>Light Blue</td>
</tr>
<tr>
<td>&lt; 30,000</td>
<td>Light Blue</td>
</tr>
<tr>
<td>&lt; 50,000</td>
<td>Light Blue</td>
</tr>
<tr>
<td>&gt; 50,000</td>
<td>Red</td>
</tr>
</tbody>
</table>

night-time
Population Structure (District of Lima, Peru)

Age class below 5 years (source: INEI of 2013)
Population Structure (District of Lima, Peru)

Age class below 5 – 24 years (source: INEI of 2013)
### Population Structure (District of Lima, Peru)

Age class below 25 – 39 years (source: INEI of 2013)

<table>
<thead>
<tr>
<th>District</th>
<th>0%</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
<th>60%</th>
<th>70%</th>
<th>80%</th>
<th>90%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puente Piedra</td>
<td>10</td>
<td>41</td>
<td>24</td>
<td>21</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Juan De Lurigancho</td>
<td>9</td>
<td>38</td>
<td>25</td>
<td>23</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Callao</td>
<td>7</td>
<td>31</td>
<td>25</td>
<td>28</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lima</td>
<td>7</td>
<td>31</td>
<td>23</td>
<td>28</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miraflores</td>
<td>4</td>
<td>21</td>
<td>24</td>
<td>34</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Puente Piedra**: 10% below 5, 41% 5 - 10, 24% 10 - 15, 21% 15 - 20, 4% 20 - 25
- **San Juan De Lurigancho**: 9% below 5, 38% 5 - 10, 25% 10 - 15, 23% 15 - 20, 5% 20 - 25
- **Callao**: 7% below 5, 31% 5 - 10, 25% 10 - 15, 28% 15 - 20, 8% 20 - 25
- **Lima**: 7% below 5, 31% 5 - 10, 23% 10 - 15, 28% 15 - 20, 11% 20 - 25
- **Miraflores**: 4% below 5, 21% 5 - 10, 24% 10 - 15, 34% 15 - 20, 17% 20 - 25
Population Structure (District of Lima, Peru)

Age class below 40 – 64 years (source: INEI of 2013)
Population Structure (District of Lima, Peru)

Age class 65 years and older (source: INEI of 2013)
Main benefits:

- Standardized process for urban mapping and analyze in mid-scale level for data scare areas
- The retrospective view give us useful information of urban growth patterns
- Cost & time efficient way to derive geospatial information about the urban structure
- Link to socioeconomic data
- Detection of hotspot areas for natural hazards (vulnerability)
- Important input to make the urban area more resilient
Thank you for your attention

IABG mbH

Dr. Rainer Malmberg
Business Development
Einsteinstraße 20
D-85503 Ottobrunn
Germany
Tel +49 89 6088 2823
Fax +49 351 8923 2355
E-Mail malmberg@iabg.de
Web www.iabg.de

Elke Kraetzschmar
Senior Specialist in Image Analysis & Remote Sensing
Hermann-Reichelt-Str.3
D-01109 Dresden
Germany
Tel +49 351 8923 145
Fax +49 351 8923 2355
E-Mail kraetzschmar@iabg.de
Web www.iabg.de