Annual World Bank Conference on Land and Poverty
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World Bank HQ, Washington DC, USA

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

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Background: The Project

Monitoring Urbanization in Latin American Metropolitan Areas

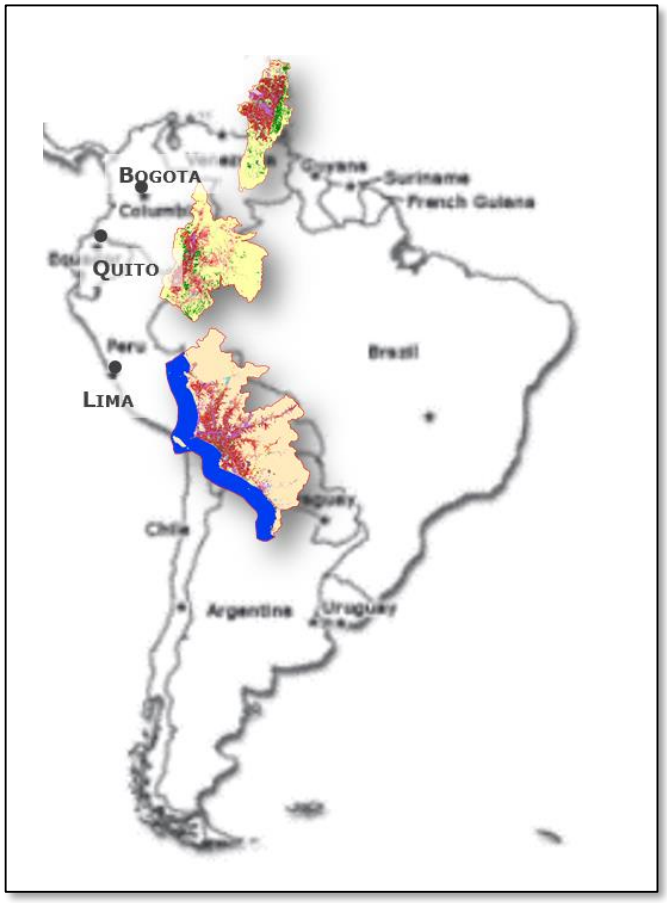
... a project focusing on preparation of demonstration cases for Urban Mapping

within the context of

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

key users

Service design,
preparation & analysis

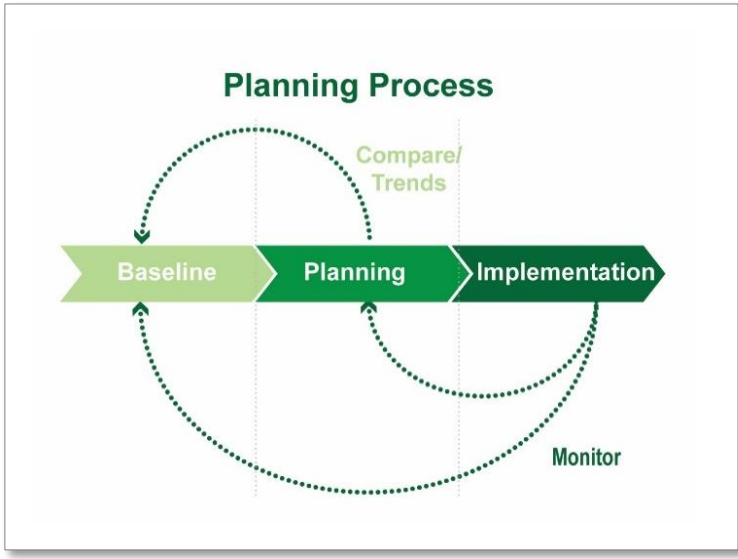


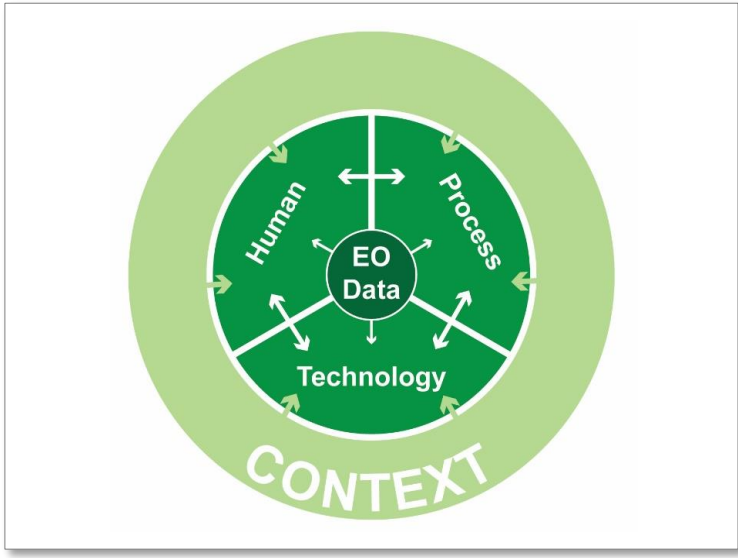
Background: The World Bank Project

Monitoring Urbanization in Latin American Metropolitan Areas

Main objectives:

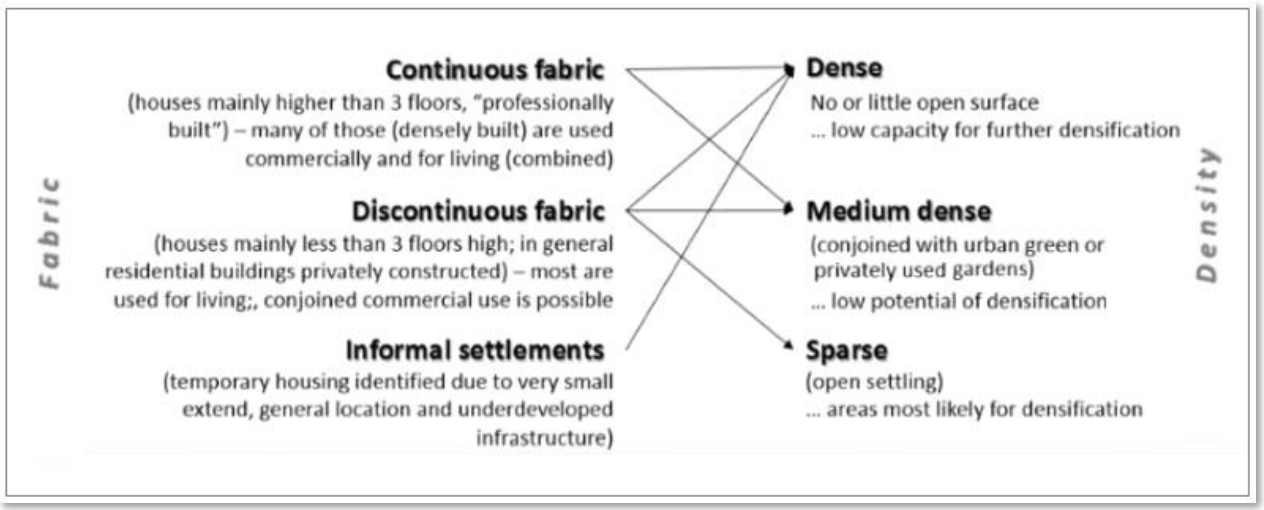
- Development of a **time & cost efficient** process for urban structure analysis
- The **capability of Earth Observation** as suitable basis for baseline mapping, urban planning and monitoring
- Establish standard procedure to create **comparable results on a global level** (*Urban Atlas* classification)
- **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

http://www.mtritter.org/travel/Bolivia_Paraguay_Uruguay/slides/DSC_3004.JPG



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

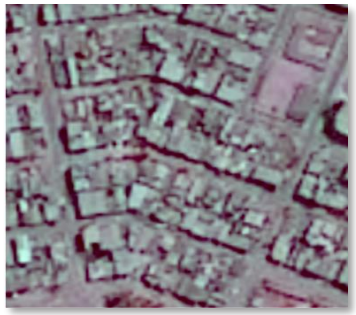
- Formal/ Informal structures relate to image texture (small features, often crowded)

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

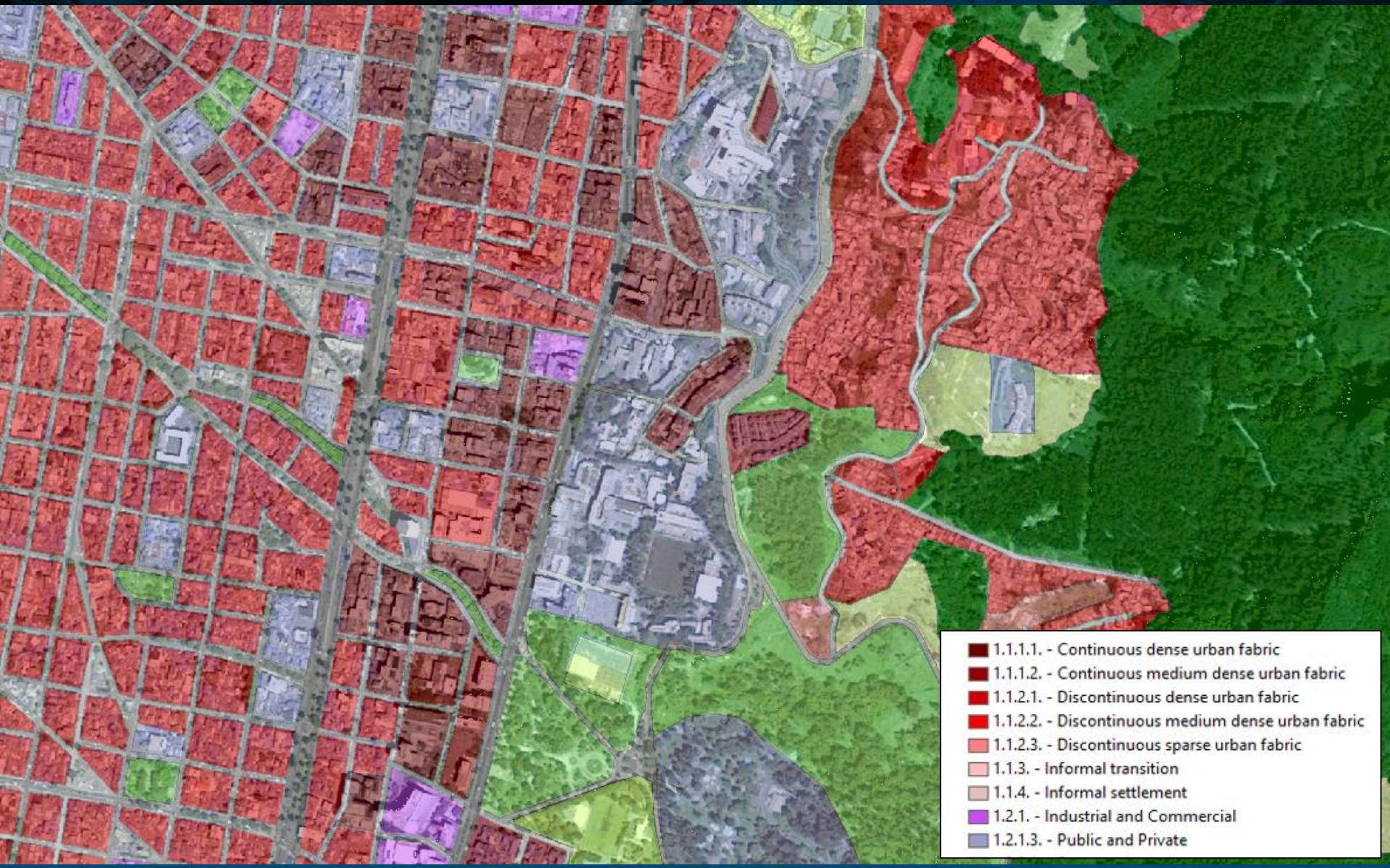
Discontinuous sparse urban fabric

Informal settlement

Source: ESRI Basemap; Google street view

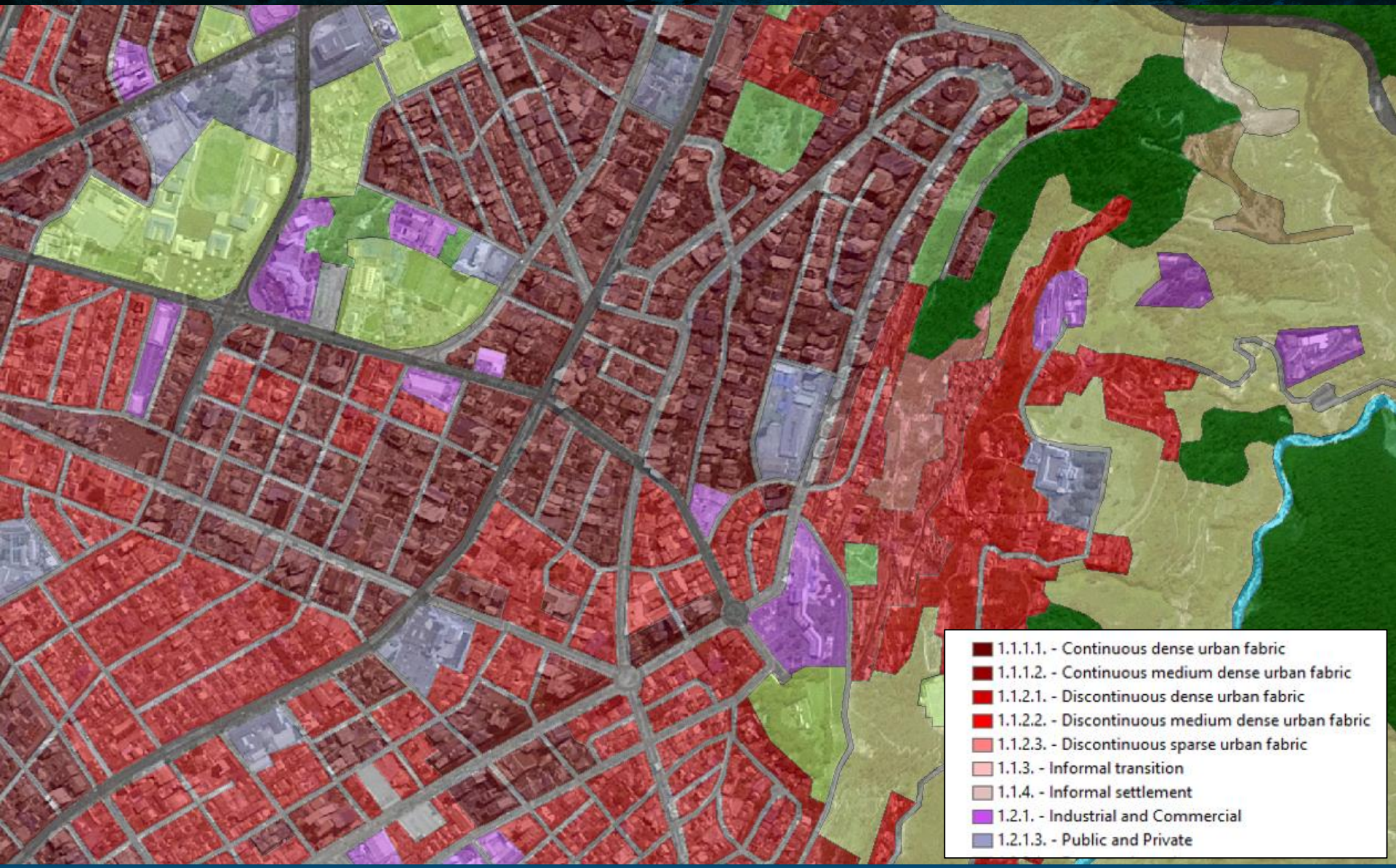
Urban Atlas - Logic of 6 different housing classes

Bogota



Urban Atlas - Logic of 6 different housing classes

Quito



Urban Atlas - Logic of 6 different housing classes

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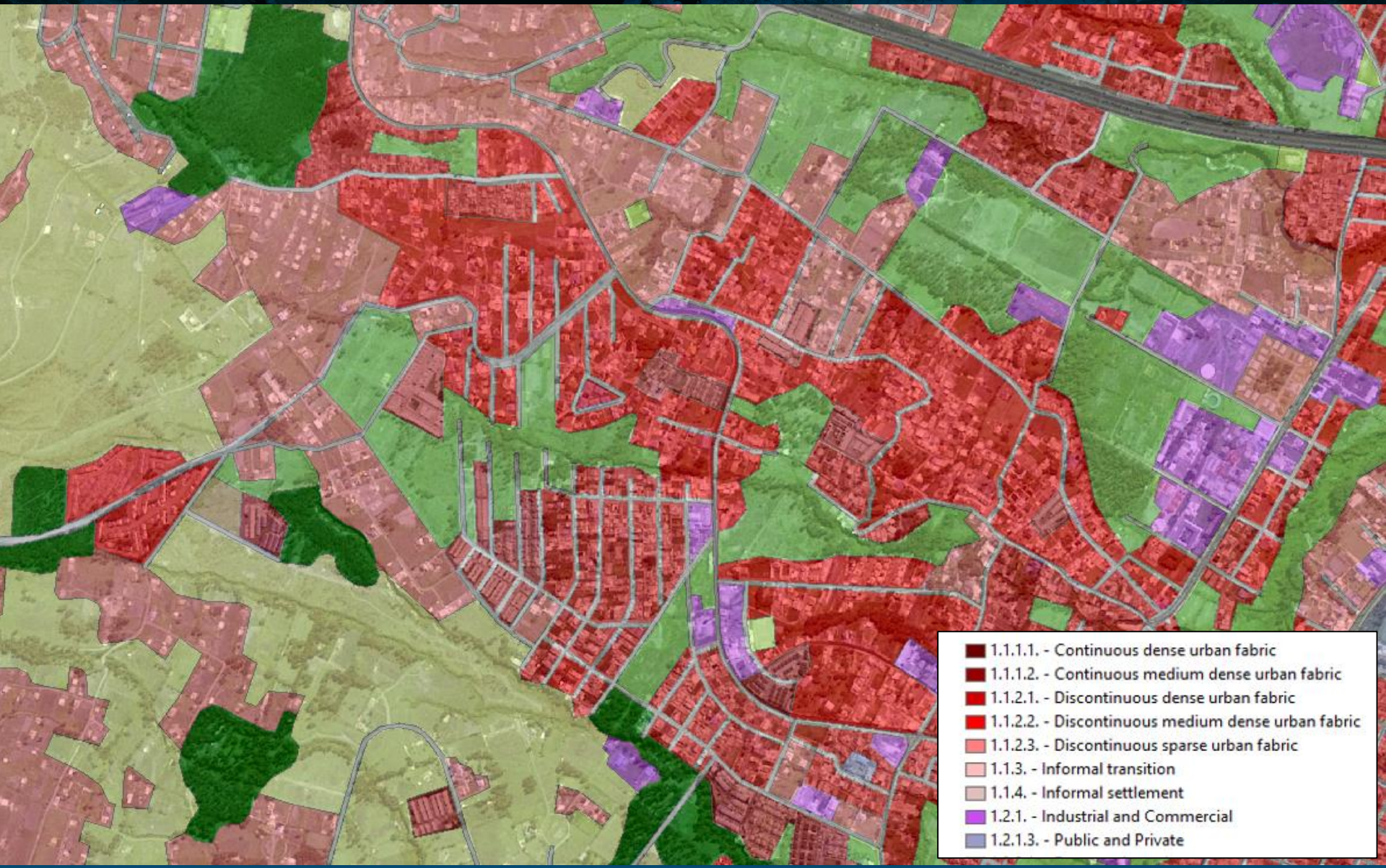
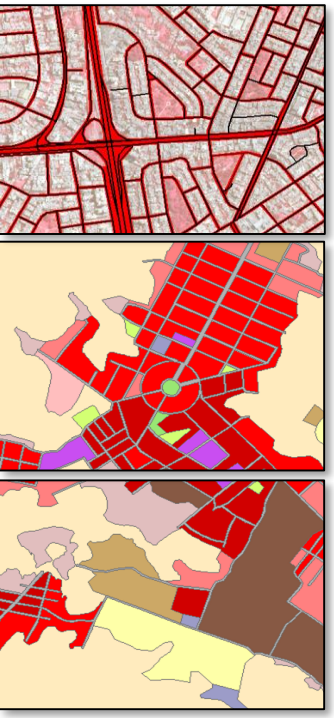


Urban Baseline Services

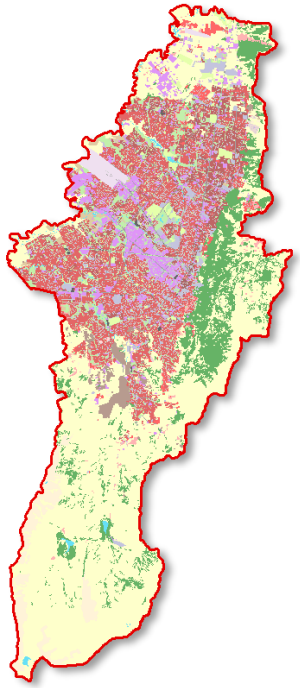


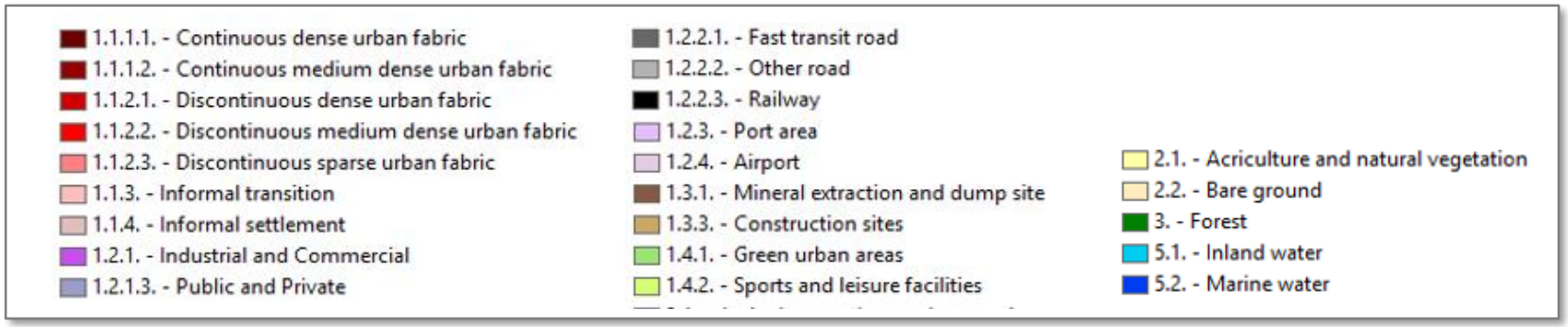
Transportation network 2013

- 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)
- 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





Urban Baseline Services

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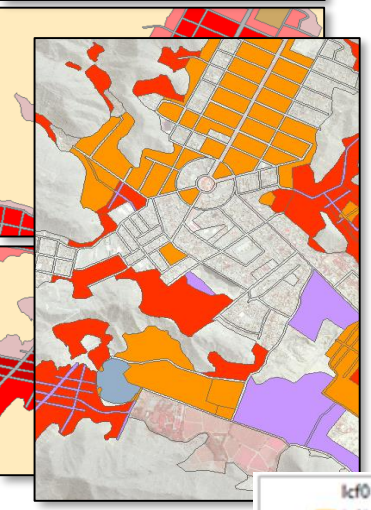
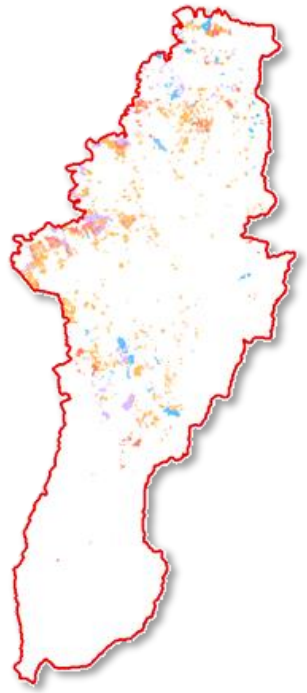


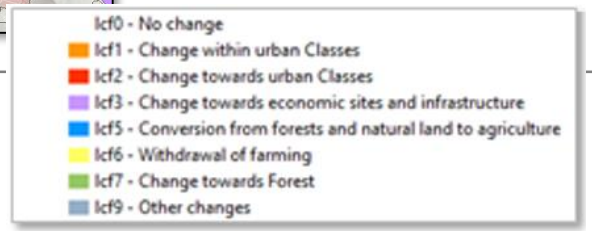
Urban Service 2013 and 2000

- Urban Atlas Standard
  (minimum mapping unit 0,25/ 1ha)

⇨ Urban Change Layer

- detailed change types
- grouped into main change characteristics



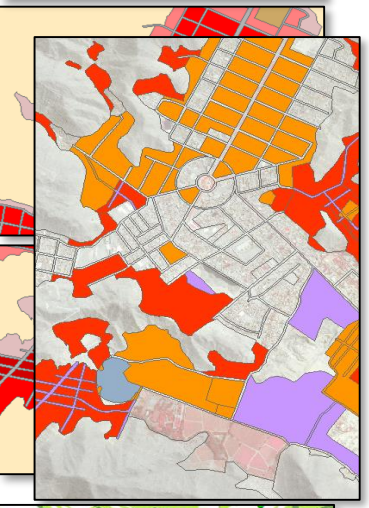


2013	1.1.1.1	1.1.1.2	1.1.2.1	1.1.2.2	1.1.2.3	1.1.3	1.1.4	1.2.1	1.2.1.3	1.2.2.1	1.2.2.2	1.2.2.3	1.2.3	1.2.4	1.3.1	1.3.3	1.4.1	1.4.2	2.1	2.2	3	5.1	5.2
2000 Code00/Code13	1111	1112	1121	1122	1123	113	114	121	1213	1221	1222	1223	123	124	131	133	141	142	21	22	3	51	52
1.1.1.1. - Continuous dense urban fabric	1111	lcf0	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.1.1.2. - Continuous medium dense urban fabric	1112	lcf13	lcf0	lcf13	lcf11	lcf12	lcf12	lcf12	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.1.2.1. - Discontinuous dense urban fabric	1121	lcf13	lcf11	lcf0	lcf13	lcf12	lcf12	lcf12	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.1.2.2. - Discontinuous medium dense urban fabric	1122	lcf13	lcf11	lcf13	lcf0	lcf12	lcf12	lcf12	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.1.2.3. - Discontinuous sparse urban fabric	1123	lcf13	lcf11	lcf13	lcf11	lcf0	lcf12	lcf12	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.1.3. - Informal transition	113	lcf13	lcf11	lcf11	lcf13	lcf11	lcf0	lcf12	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.1.4. - Informal settlement	114	lcf13	lcf11	lcf11	lcf13	lcf11	lcf11	lcf0	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.2.1. - Industrial and Commercial	121	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf0	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.2.1.3. - Public and Private	1213	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf0	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.2.2.1. - Fast transit road	1221	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf0	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.2.2.2. - Other road	1222	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf0	lcf12	lcf12	lcf12	lcf12	lcf12	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.2.2.3. - Railway	1223	lcf12	lcf12	lcf13	lcf12	lcf12	lcf12	lcf12	lcf12	lcf13	lcf12	lcf0	lcf12	lcf12	lcf12	lcf13	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.2.3. - Port area	123	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf0	lcf12	lcf12	lcf12	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.2.4. - Airport	124	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf0	lcf12	lcf12	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.3.1. - Mineral extraction and dump site	131	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf0	lcf12	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.3.3. - Construction sites	133	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf0	lcf13	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.4.1. - Green urban areas	141	lcf13	lcf11	lcf11	lcf11	lcf13	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf0	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
1.4.2. - Sports and leisure facilities	142	lcf13	lcf11	lcf11	lcf11	lcf13	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf0	lcf38	lcf54	lcf91	lcf72	lcf92	lcf93
2.1. - Agriculture and natural vegetation	21	lcf23	lcf23	lcf23	lcf23	lcf32	lcf32	lcf31	lcf31	lcf32	lcf32	lcf33	lcf34	lcf35	lcf37	lcf18	lcf38	lcf0	lcf62	lcf61	lcf92	lcf93
2.2. - Bare ground	22	lcf23	lcf23	lcf23	lcf23	lcf32	lcf32	lcf31	lcf31	lcf32	lcf32	lcf32	lcf33	lcf34	lcf35	lcf37	lcf18	lcf38	lcf52	lcf0	lcf72	lcf92	lcf93
3. - Forest	3	lcf23	lcf23	lcf23	lcf23	lcf32	lcf32	lcf31	lcf31	lcf32	lcf32	lcf32	lcf33	lcf34	lcf35	lcf37	lcf18	lcf38	lcf51	lcf74	lcf0	lcf92	lcf93
5.1. - Inland water	51	lcf23	lcf23	lcf23	lcf23	lcf32	lcf32	lcf31	lcf31	lcf32	lcf32	lcf32	lcf33	lcf34	lcf35	lcf37	lcf18	lcf38	lcf53	lcf99	lcf72	lcf0	lcf99
5.2. - Marine water	52	lcf23	lcf23	lcf23	lcf23	lcf32	lcf32	lcf31	lcf31	lcf32	lcf32	lcf32	lcf33	lcf34	lcf35	lcf37	lcf18	lcf38	lcf53	lcf99	lcf72	lcf99	lcf0

Urban Services

Transportation network 2013

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

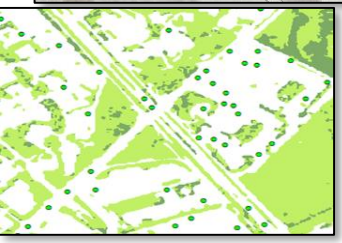


Urban Service 2013 and 2000

- Urban Atlas Standard
  (minimum mapping unit 0,25/ 1ha)

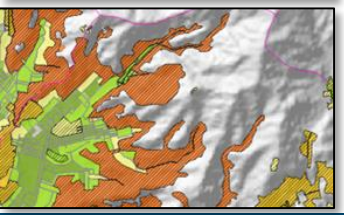
⇨ **Urban Change Layer**

- detailed change types
- grouped into main change characteristics



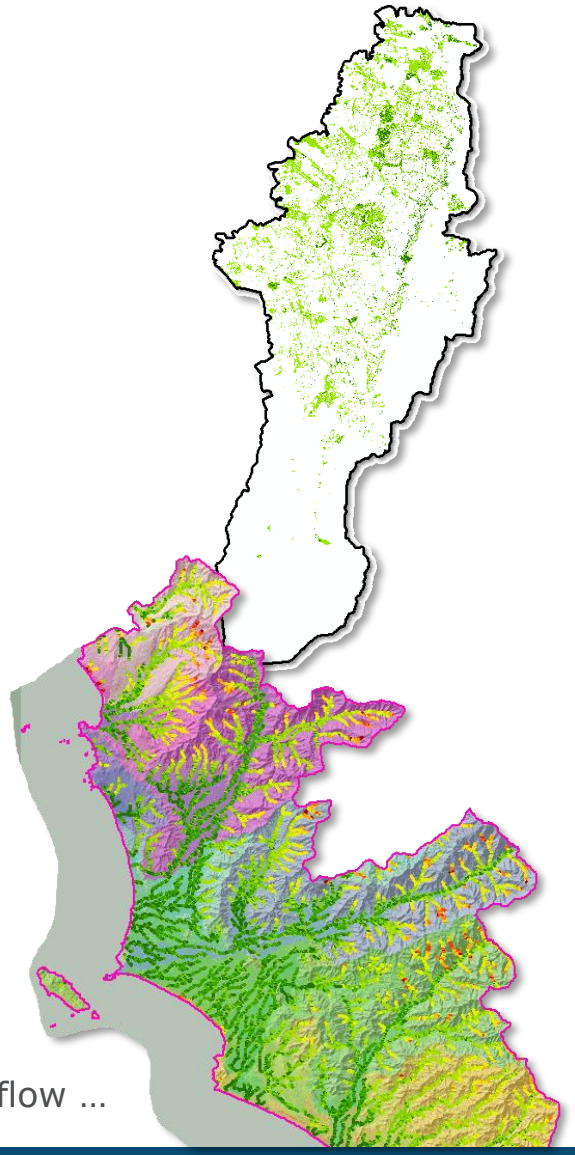
Urban Vegetation Layer 2013

- low and high vegetation
- minimum mapping unit 0,1ha
- significant single trees



Terrain Analysis

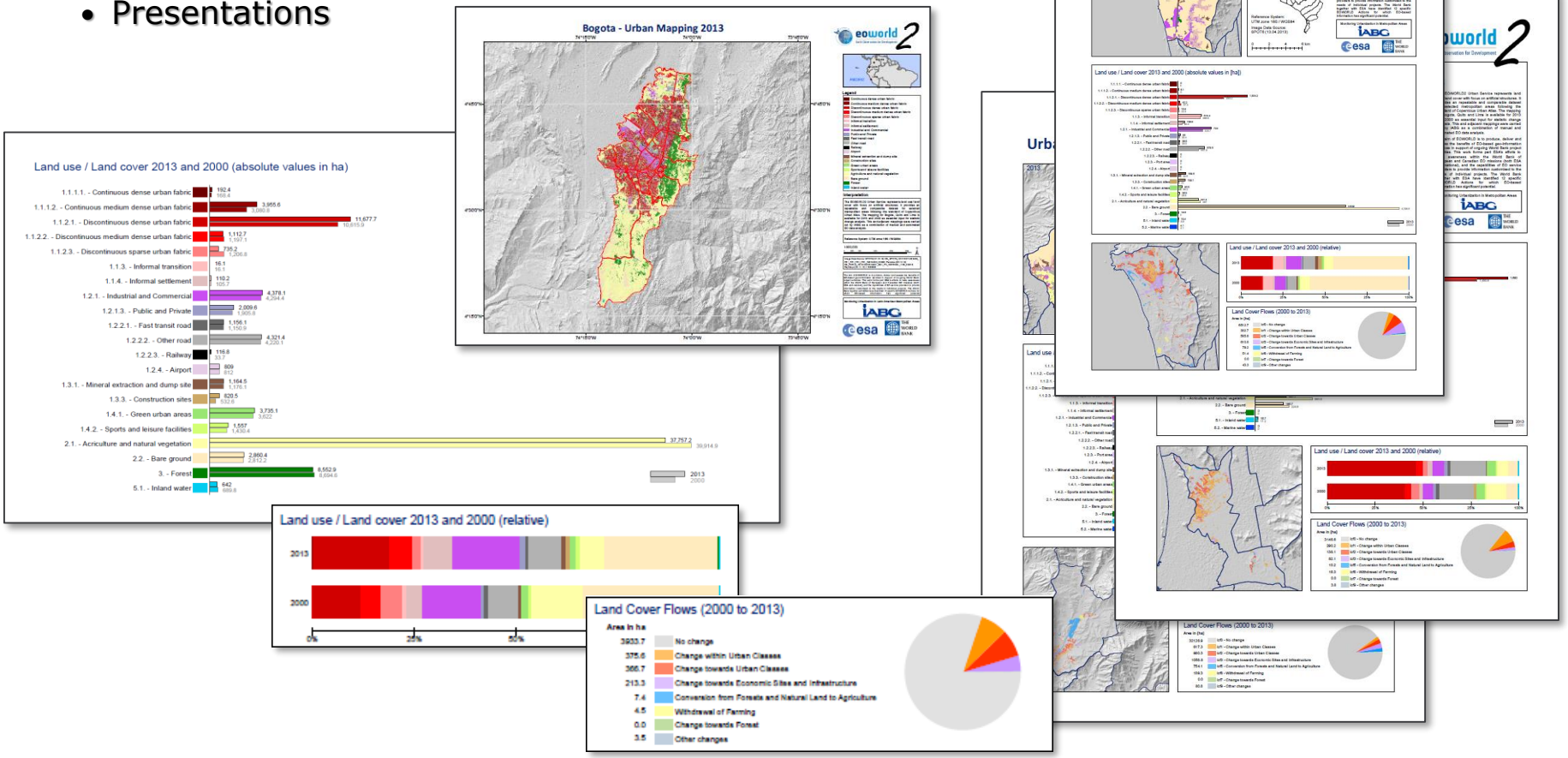
- considering Urban Mapping Service(s)
- Risk identification, calculation of natural drainage flow …



Urban Services

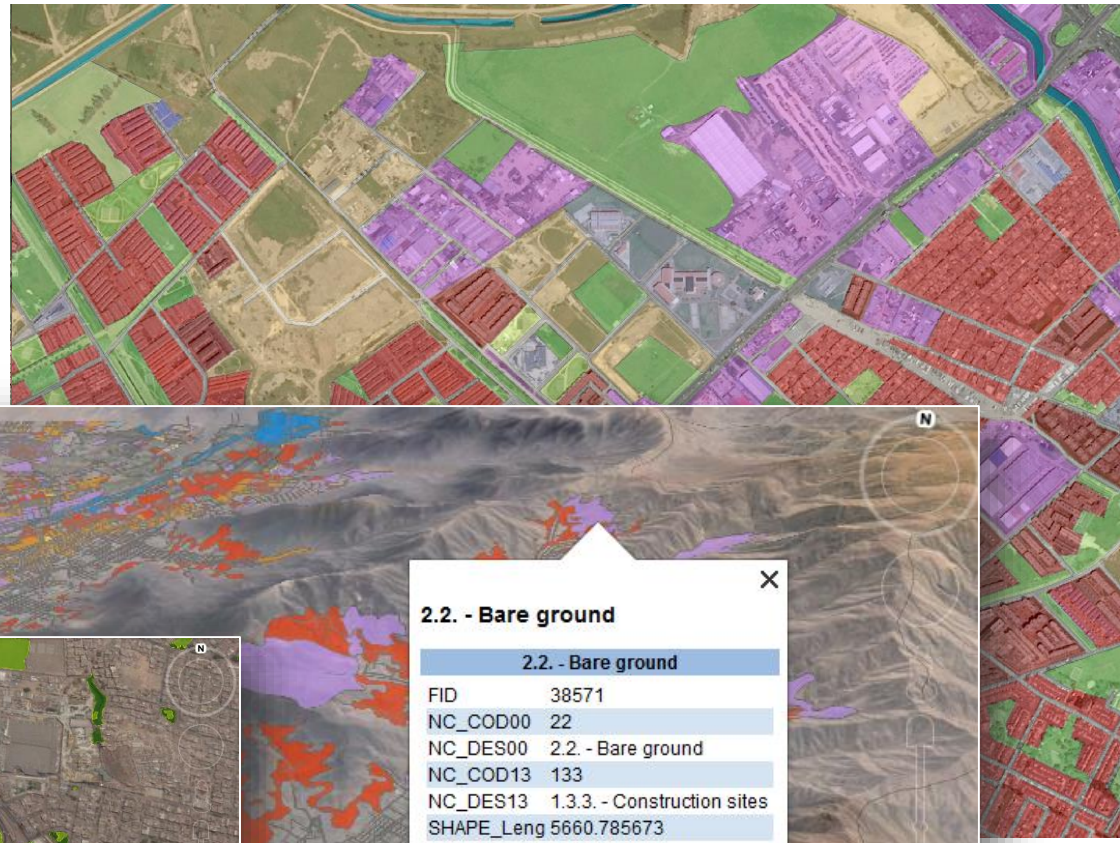
contain

- Report Series
- Statistics (absolute/ relative)
- Maps & Maps series (administrative units)
- Presentations

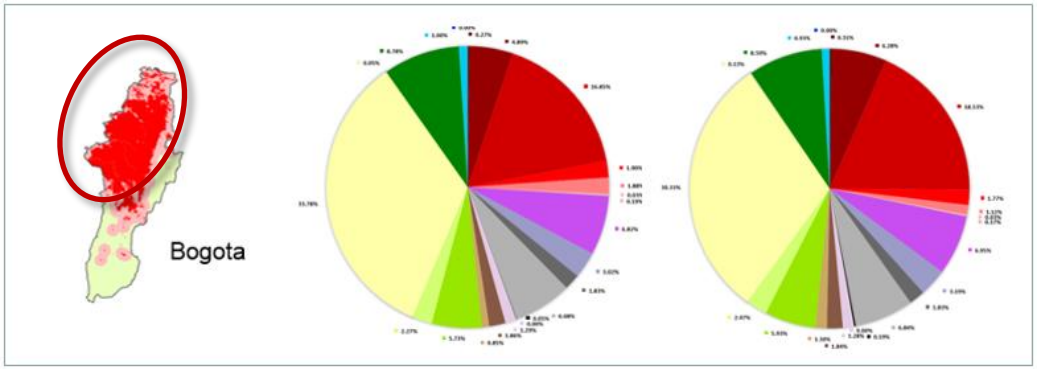


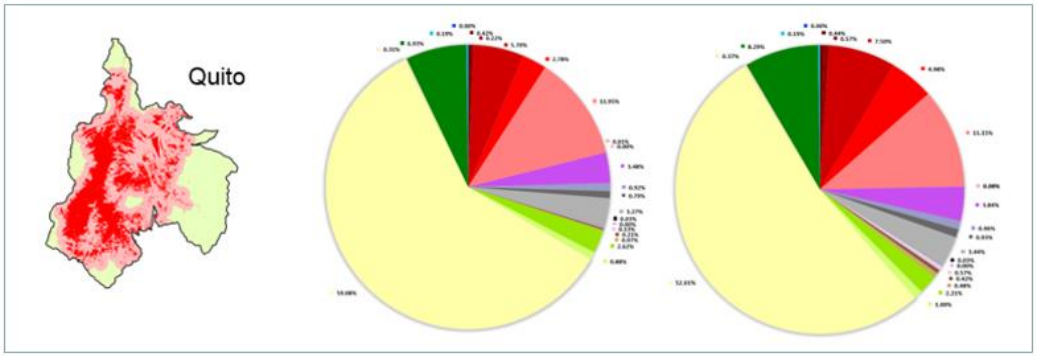
The EO Products: What They Are

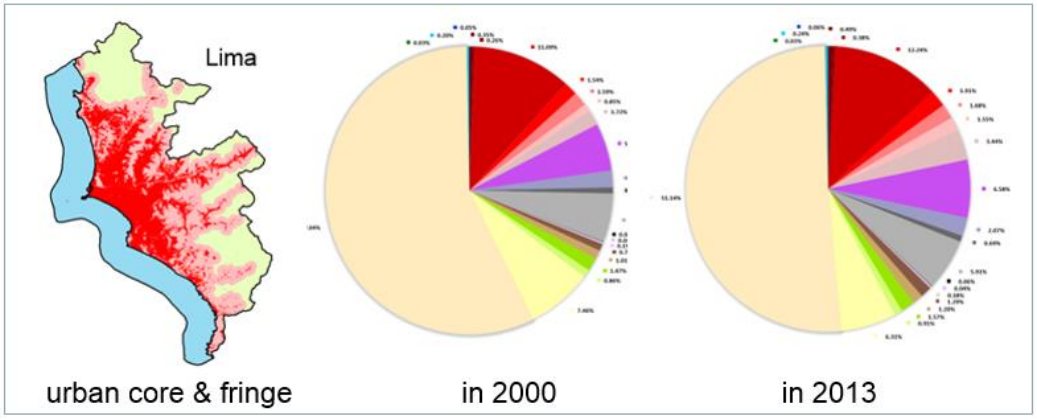
- EO data used
  - 2000: SPOT 4/5 (2,5m … 5m)
  - 2000: Landsat 7 (15m)
  - 2013: SPOT 5/6 (1,5 – 2,5m)
  - *2015: Sentinel 2 (10m resolution)*
- Data – easy to handle
  - different exchange formats (shp)
  - conform to PUMA platform
- Google-ready
  for a wider audience
  (kml)



Comparability of Metropolitan regions







Urban Atlas

- 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
- 1.1.3. - 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. - Acriculture and natural vegetation
- 2.2. - Bare ground
- 3. - Forest
- 5.1. - Inland water
- 5.2. - Marine water

comparable due to

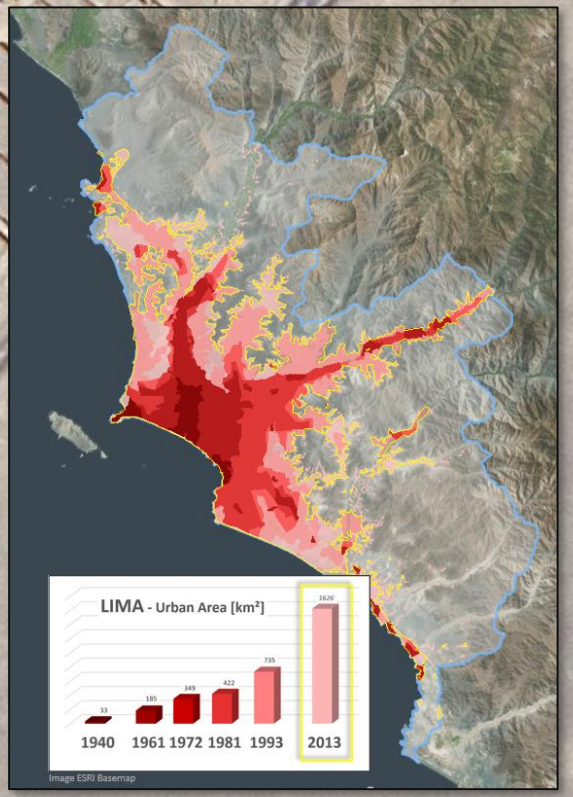
- similar dates
- similar nomenclature Urban Atlas (applied standard)
- easy to combine with other sources
- administrative units

limitations

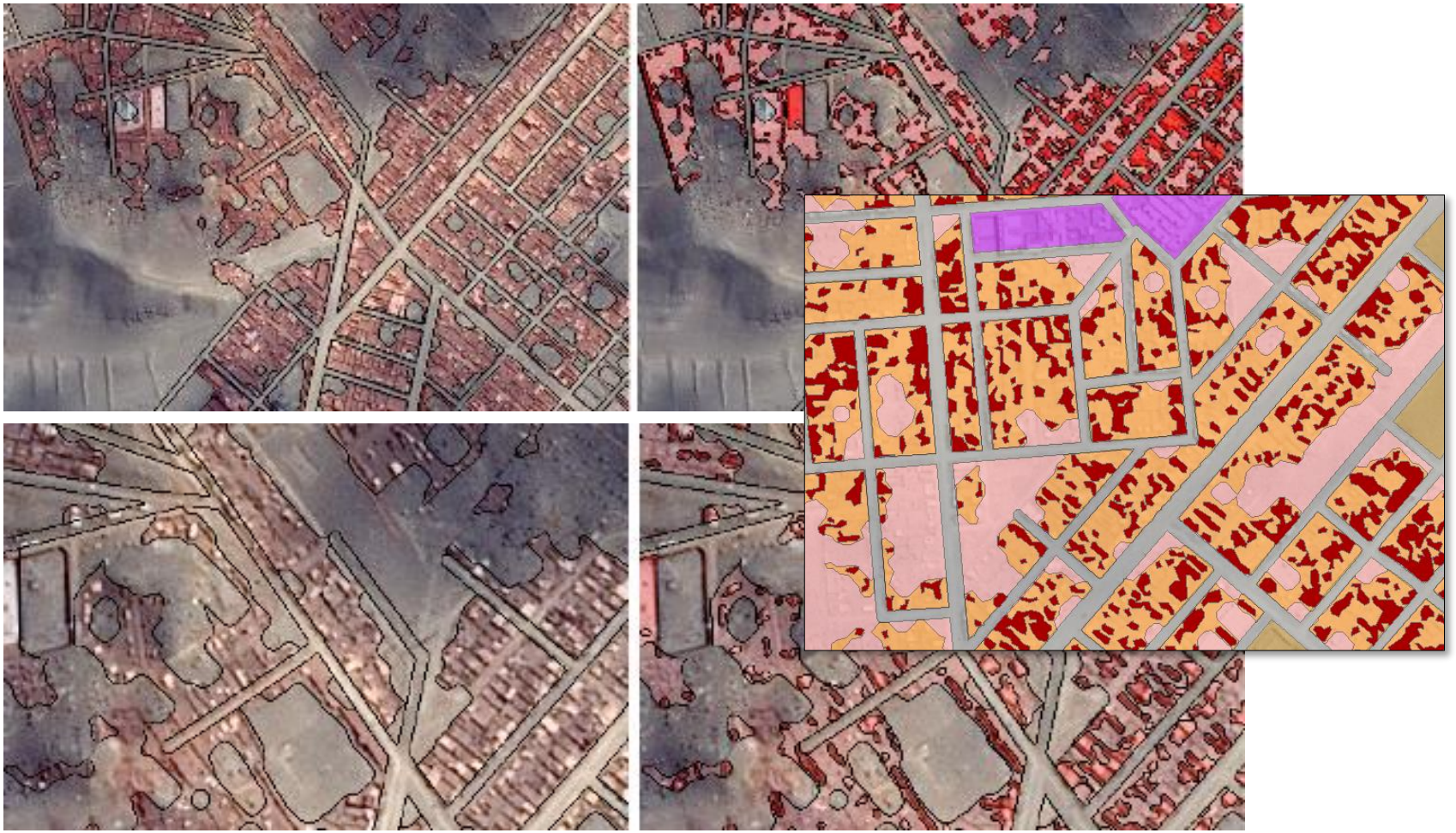
- subset definition → often related to administrative units

- Suggestion:
  core area & buffer approach, considering administrative units

Lima – Urban spreading ("informal transition")



Lima – Urban spreading ("informal transition")



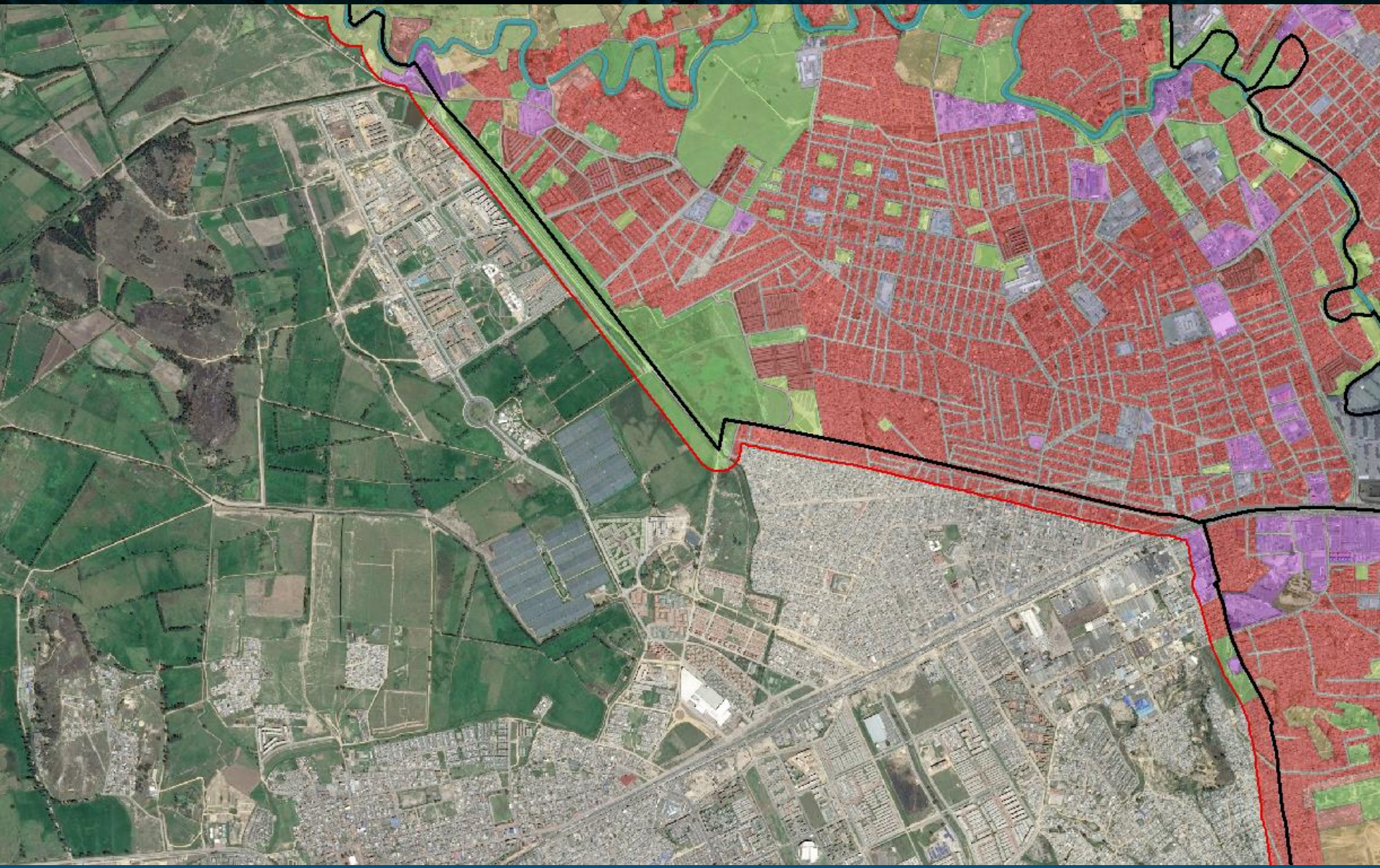
- detecting populated areas and open spaces in-between, density, & avg. size of housing
- fast, comparable and repeatable at reasonable quality

Quito – Urban Vegetation

© http://cdn.salzburg.com/nachrichten/uploads/pics/2014-11/orginal/quito-raubt-einem-den-atem-41-55580720.jpg

Urban Vegetation Layer

Bogota – Urban Area ⇔ Area with significant change



Bogota – Urban Area ⇔ Area with significant change

example Bogota

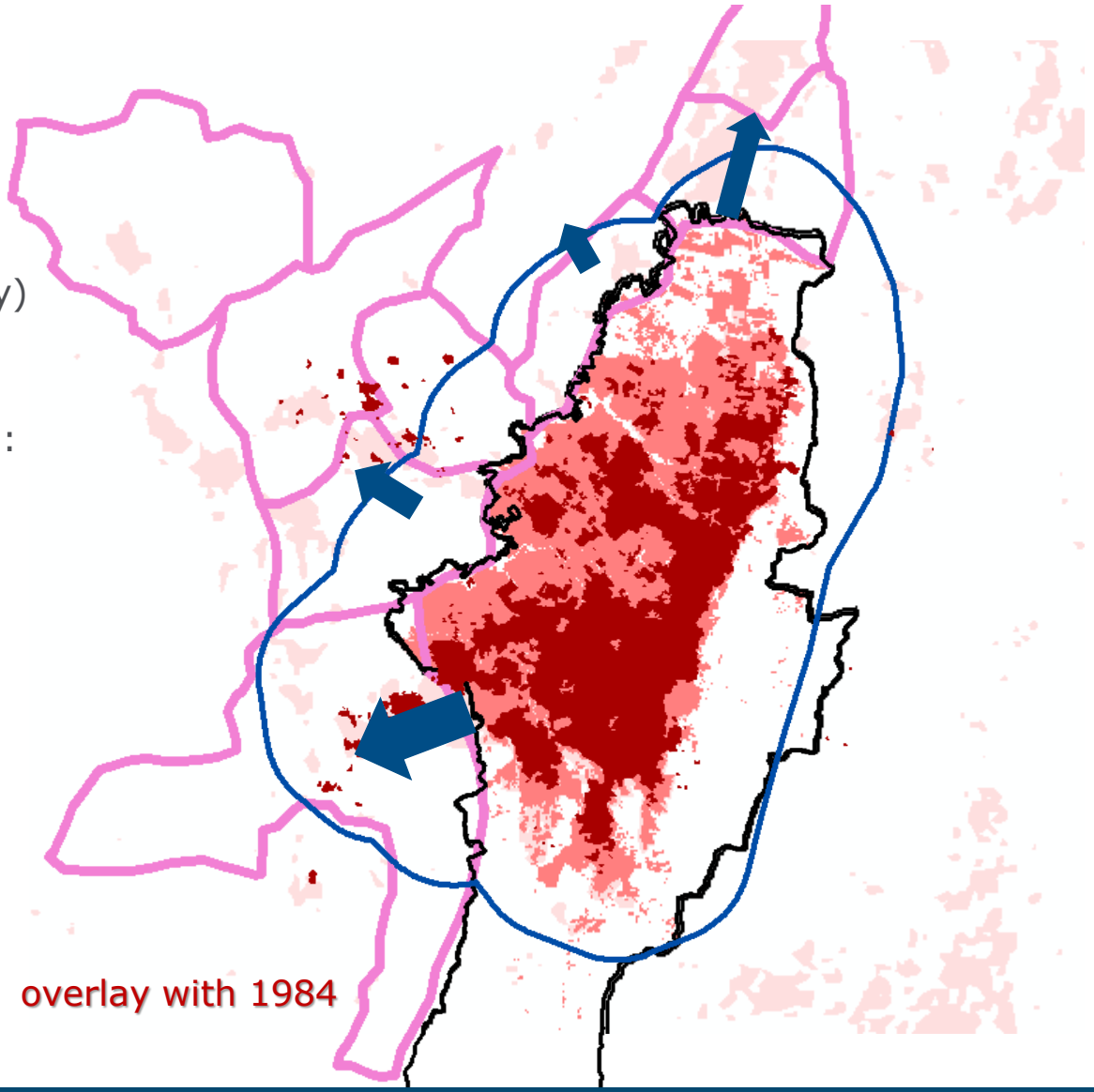
- urban core
  (up-to-date, draft classification)
- EOworld2 subset for mapping
  Mapping result 2013 (Urban only)

- calculation of buffer area
  (relative to absolute size of city):

$$r(buffer) = 0{,}25\sqrt{A(core)}$$

+ administrative Units:

map & analyse areas
under severe change



Summary: The EO Products – What They Bring

POTENTIAL INPUT

.. to save World Bank costs

+ World Bank references

GIS,
previous analysis layer

+ auxiliary data

land use,
thematic features

+ in-situ knowledge

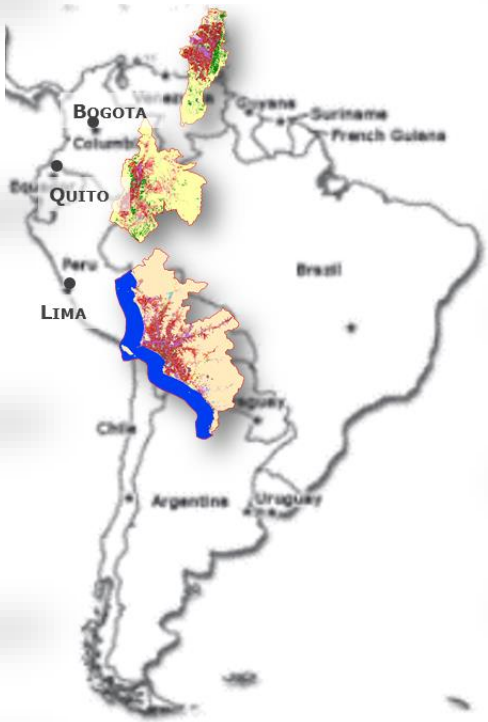
hot-spots,
special aspects of the cities

+ 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

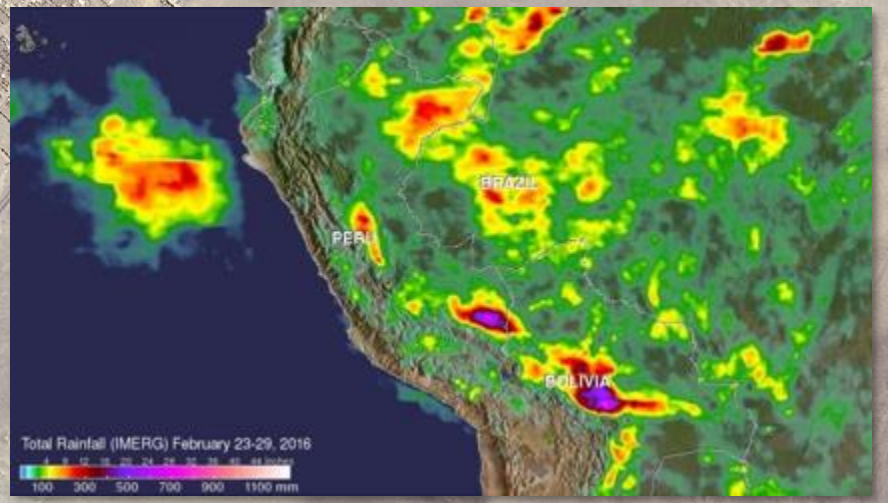
independent

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

Terrain Information for urban analysis and planning

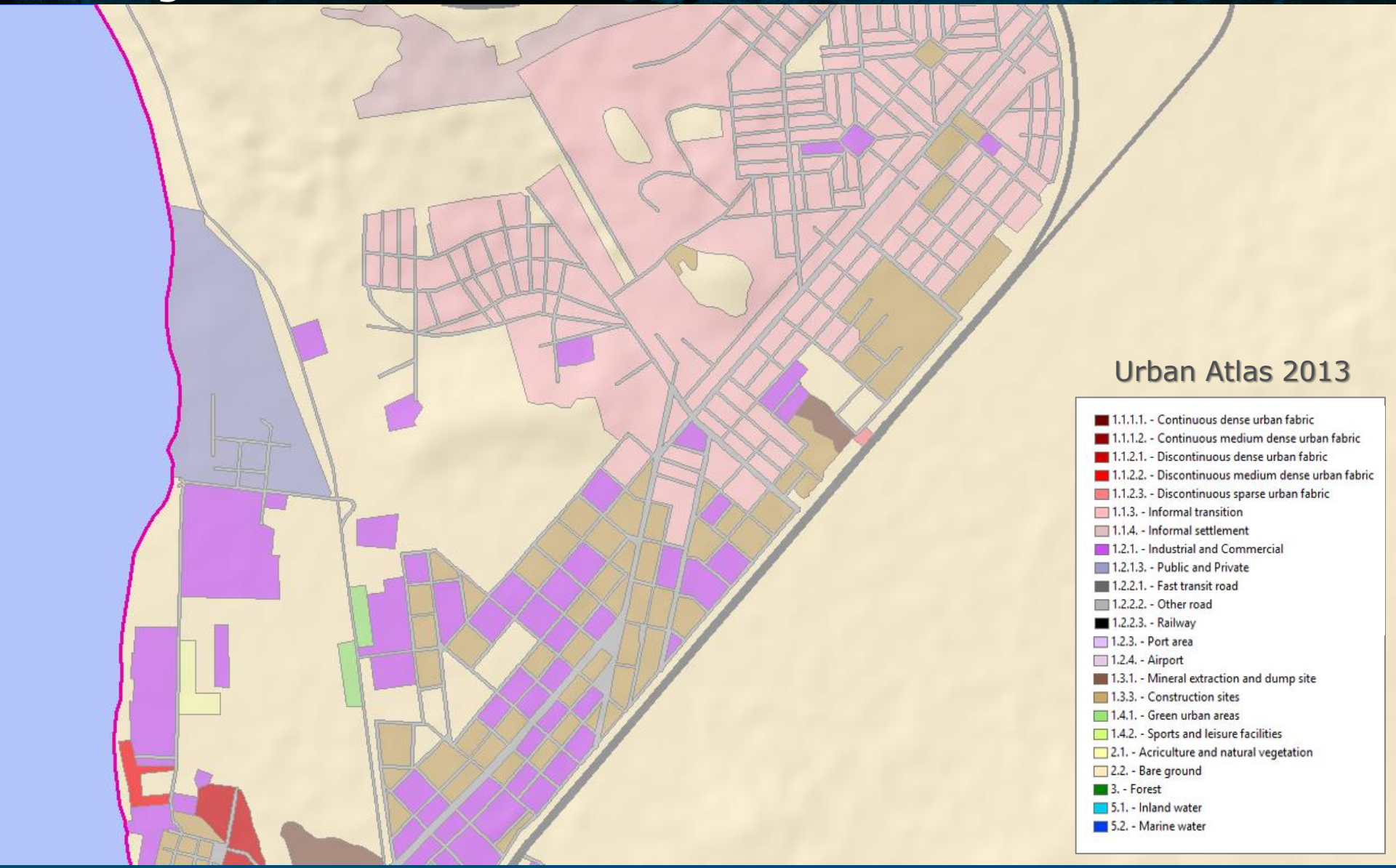
eoworld 2
Earth Observation for Development

Terrain analysis (risk identification) Climate change effects

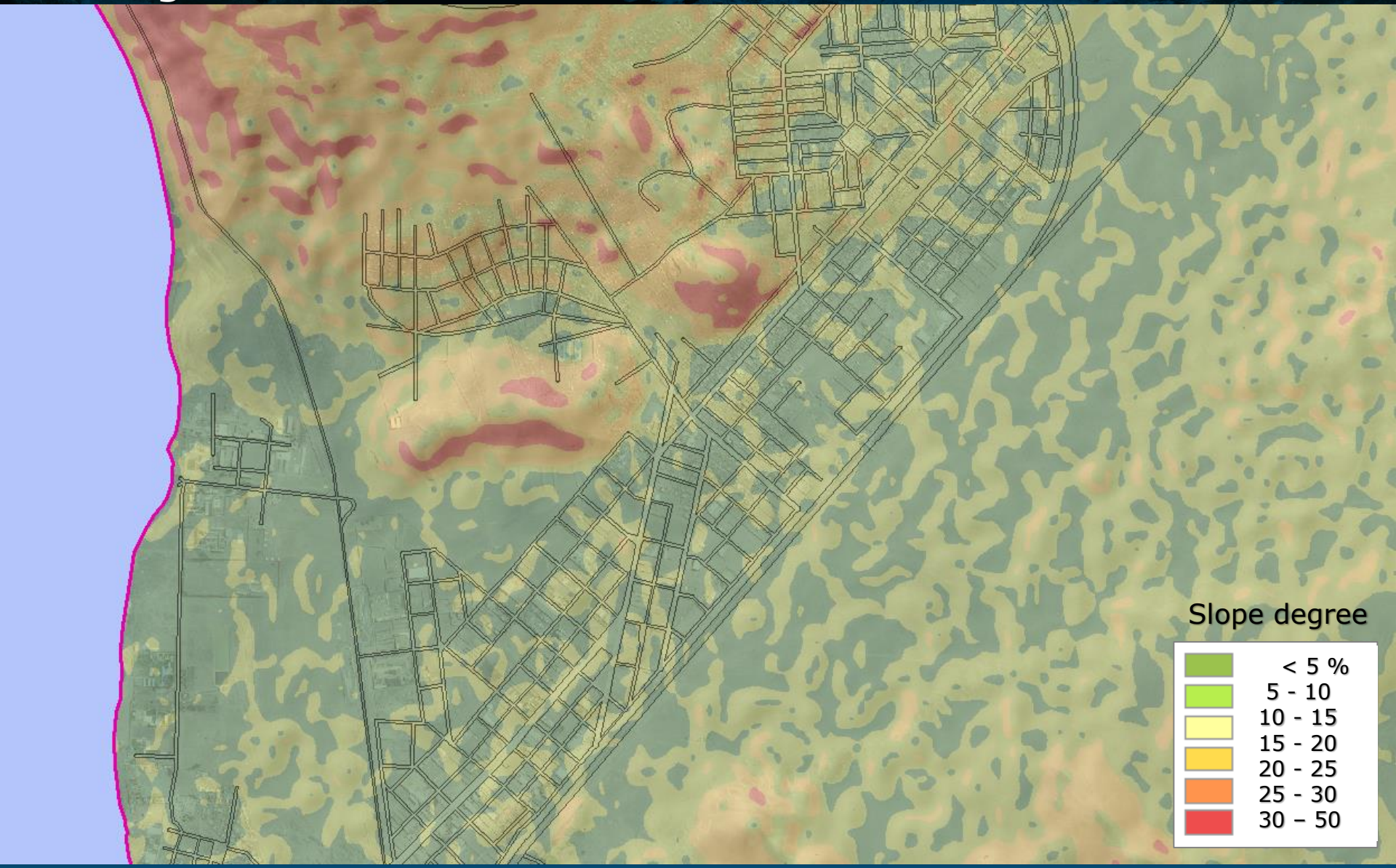


(1) http://floodlist.com/america/heavy-rain-central-southern-peru-1-dead-1-missing-february-2016
(2) (2) http://floodlist.com/america/nasa-satellites-measure-flooding-rain-in-peru-and-bolivia

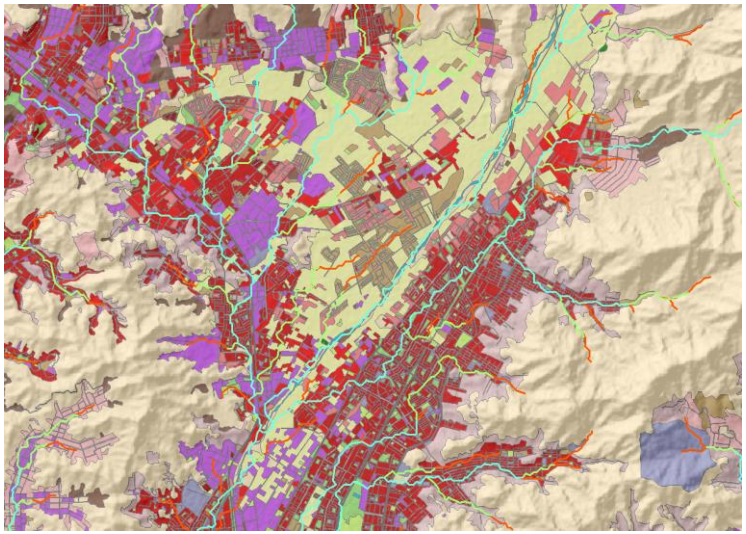
Terrain analysis (risk identification) Climate change effects



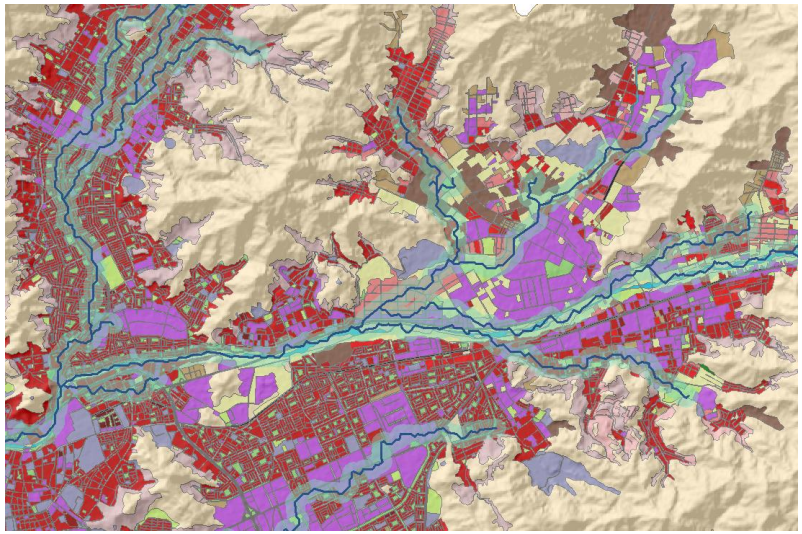
Terrain analysis (risk identification) Climate change effects



Automatic computation of natural drainage based on SRTM plus (30 m)

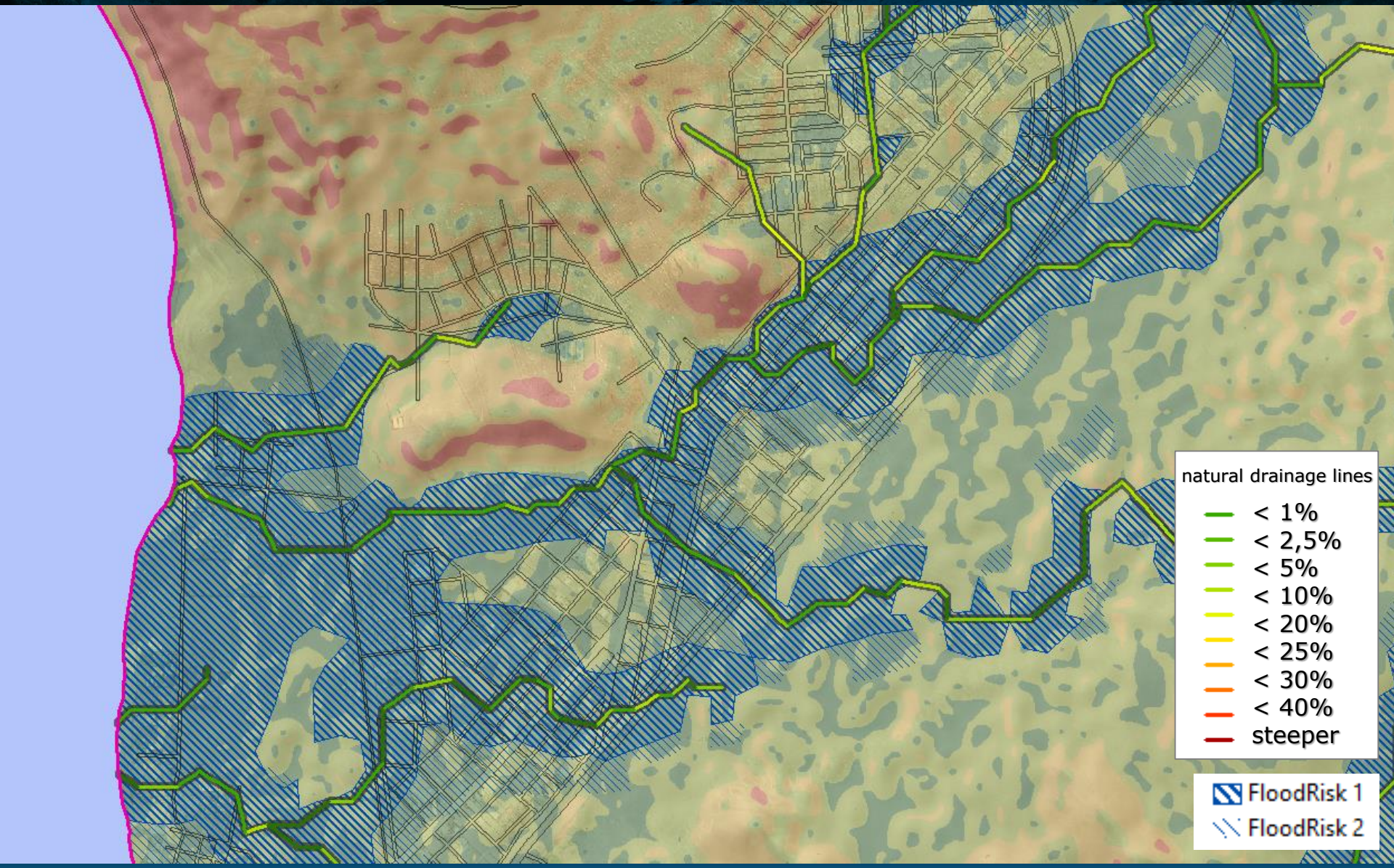


extraction of drainage lines

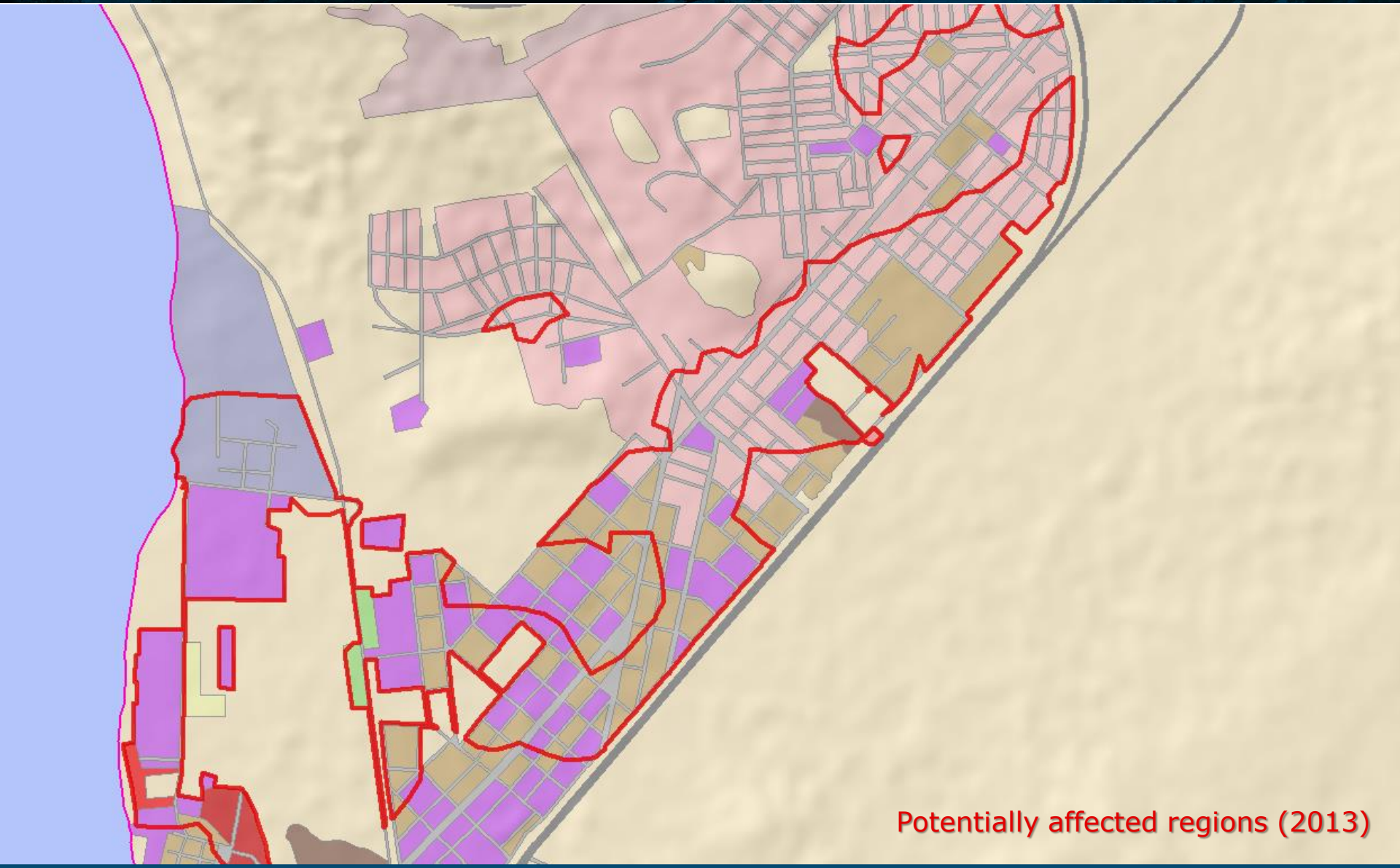


drainage lines and potential flooding areas

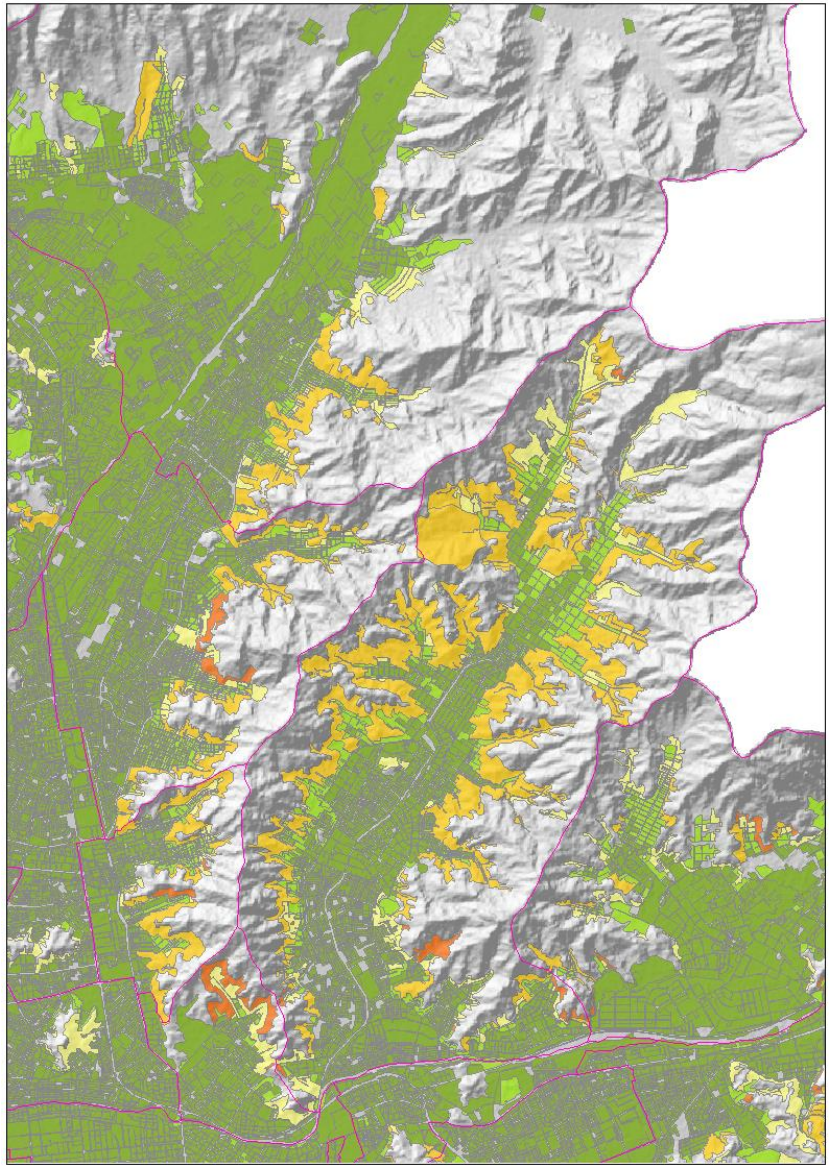
Terrain analysis (risk identification)- potential flooding zones

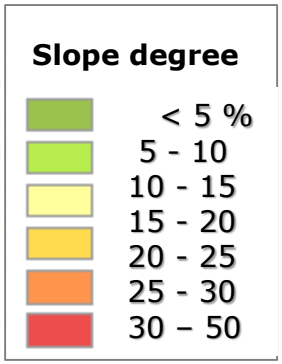


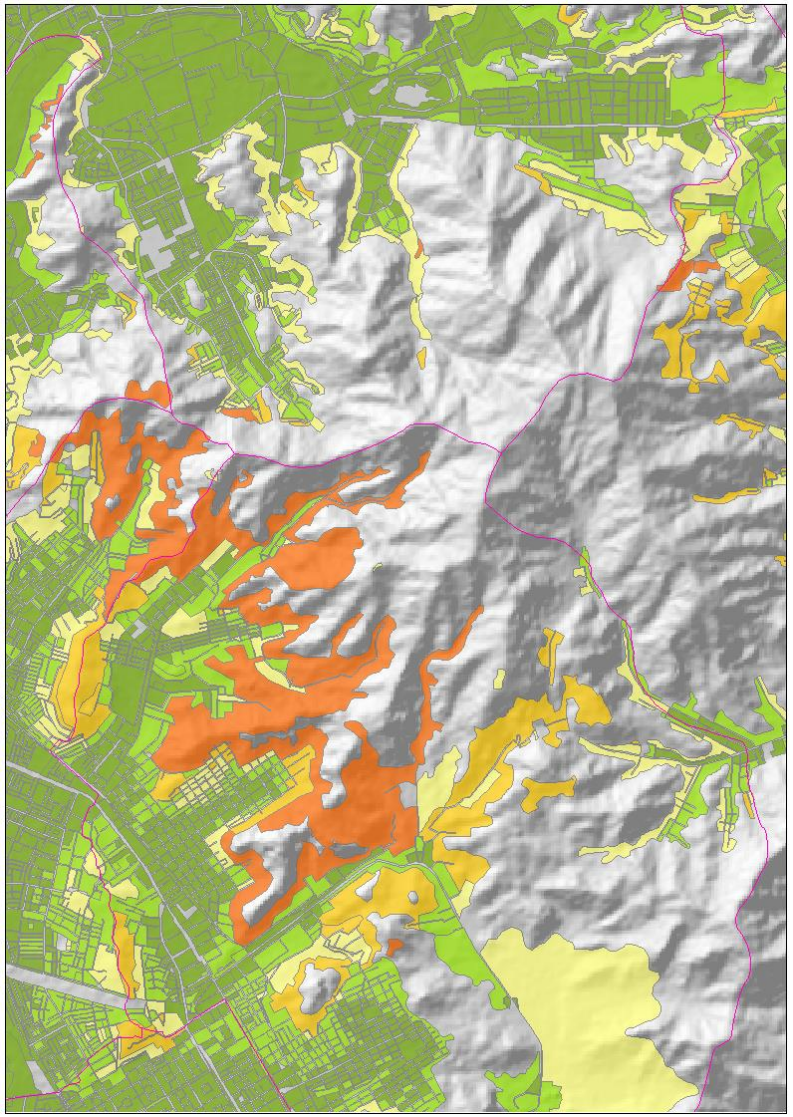
Terrain analysis (risk identification)- potential flooding zones



Slope map suburban Lima – potential landslide areas

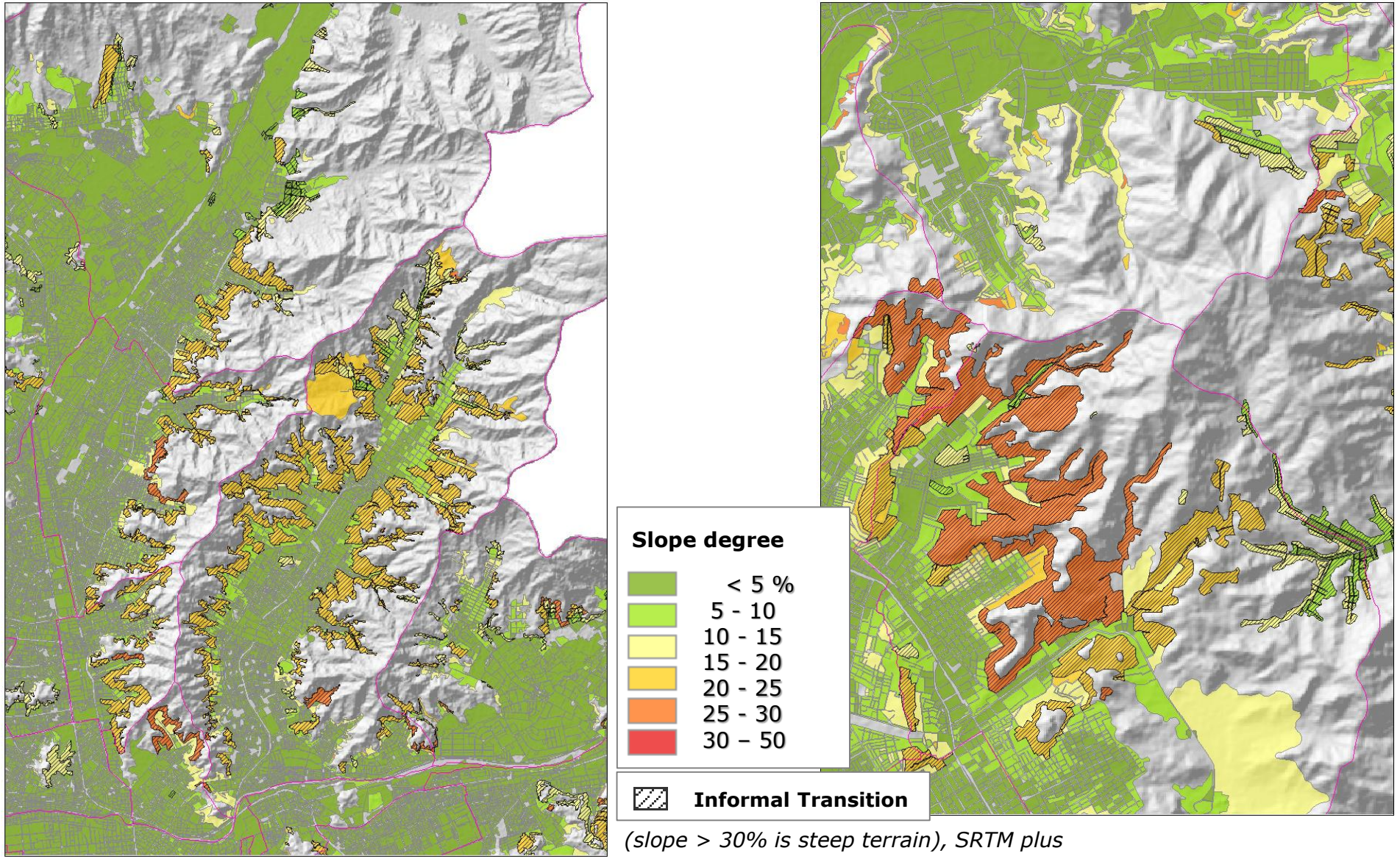






(slope > 30% is steep terrain), SRTM plus

Slope map suburban Lima – potential landslide areas



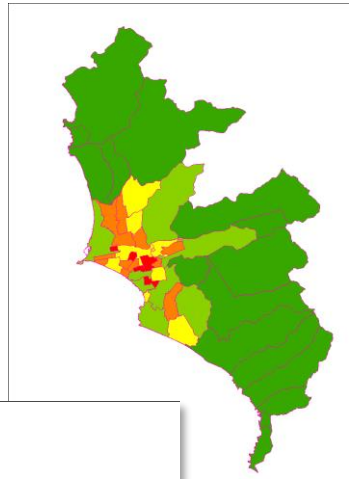
(slope > 30% is steep terrain), SRTM plus

Relation of geospatial and socioeconomic data

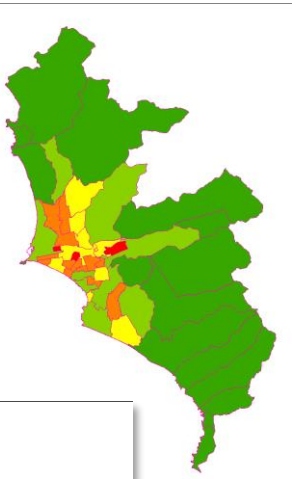
Statistic interpretation

- 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

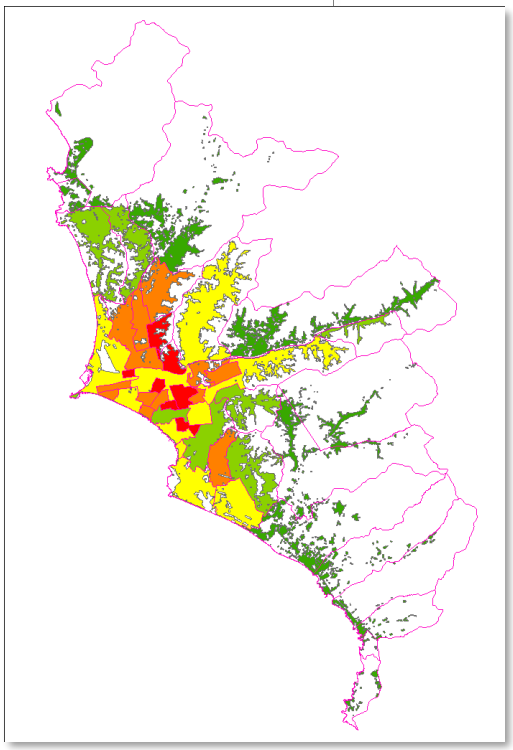


Population/km²
< 500
< 1,000
< 1,500
< 2,000
< 3,000



Lima, 2007

2013

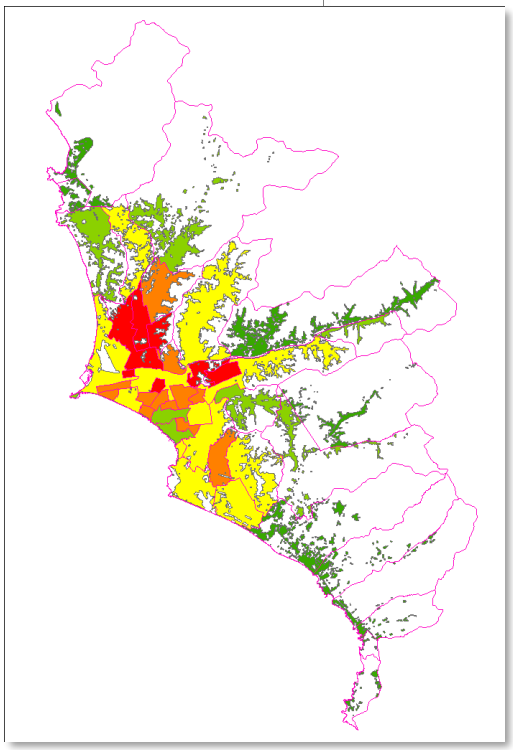


example:
population density (Lima)

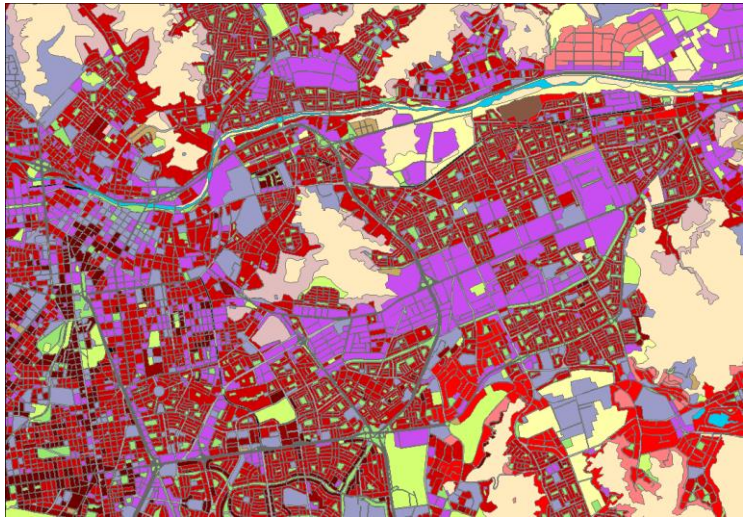
statistics related to absolute extent of administrative area are often not suitable/ pretend a different reality

real change can only be seen related to absolute urban footprint

Population/km²
< 500
< 1,000
< 15,000
< 20,000
< 30,000

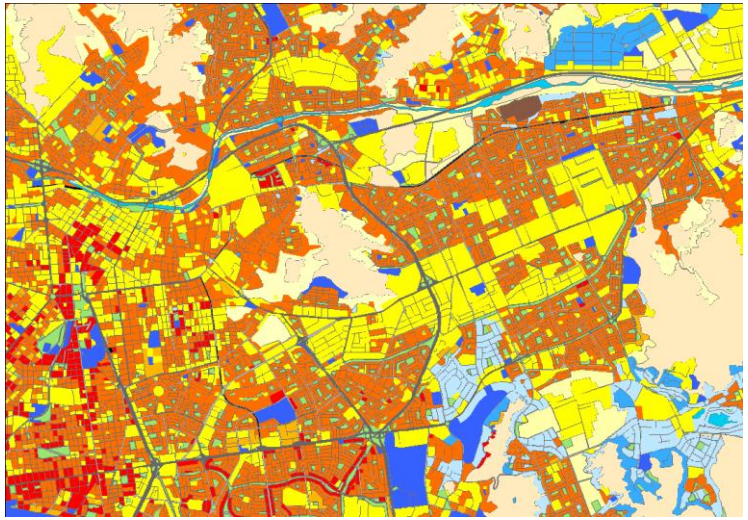


Population density

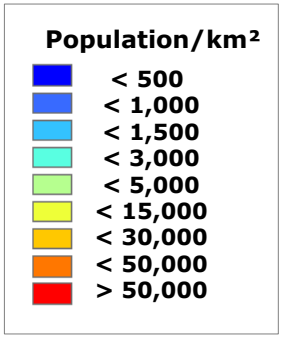


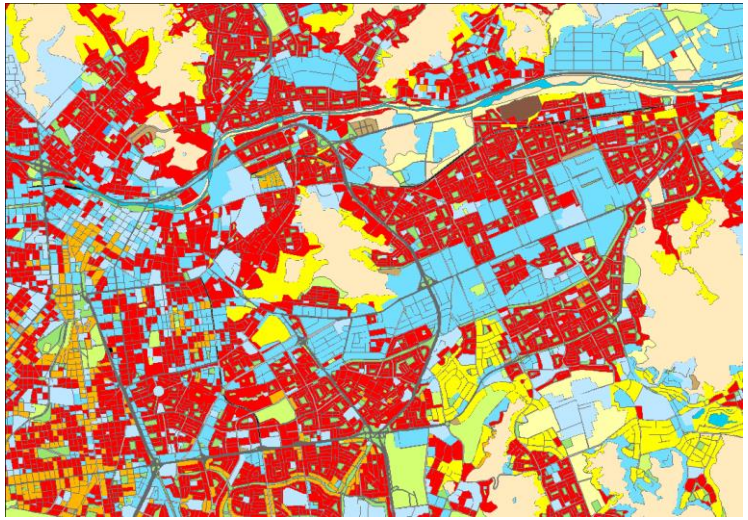
based on
Urban Mapping Service

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

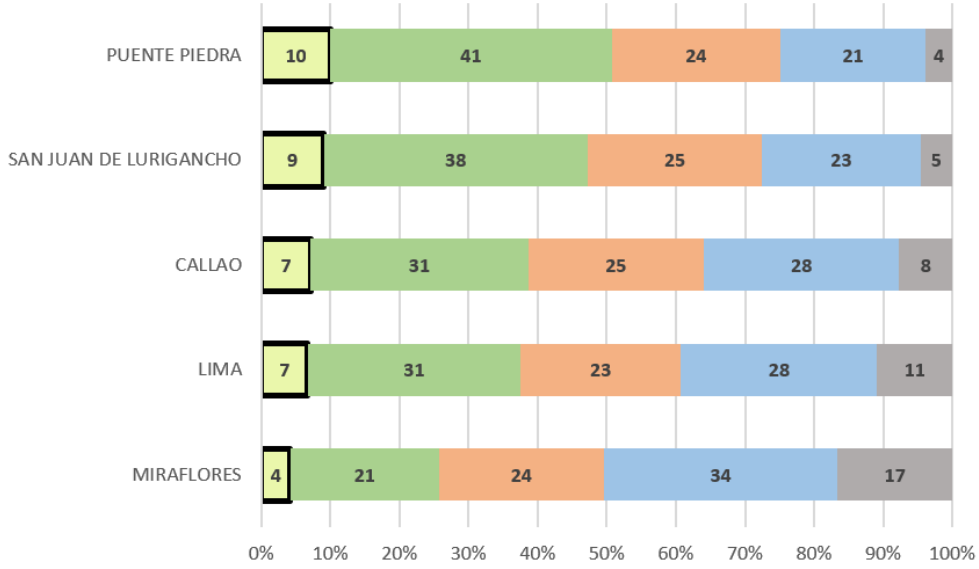


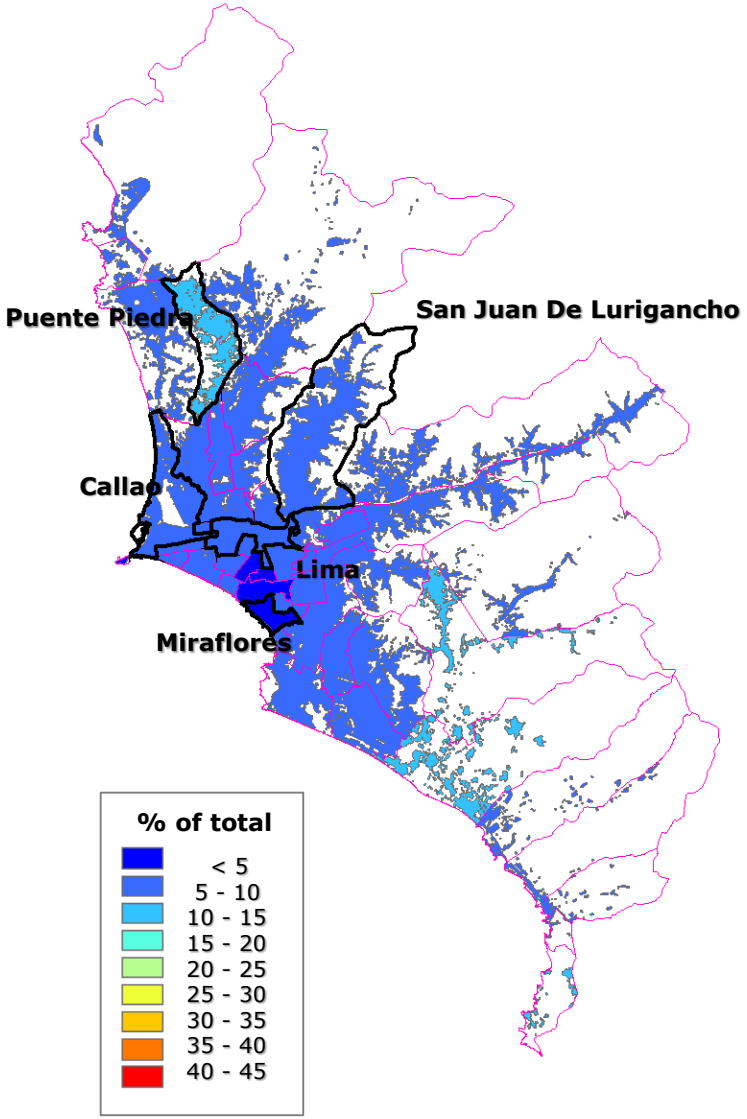


night-time

Population Structure (District of Lima, Peru)

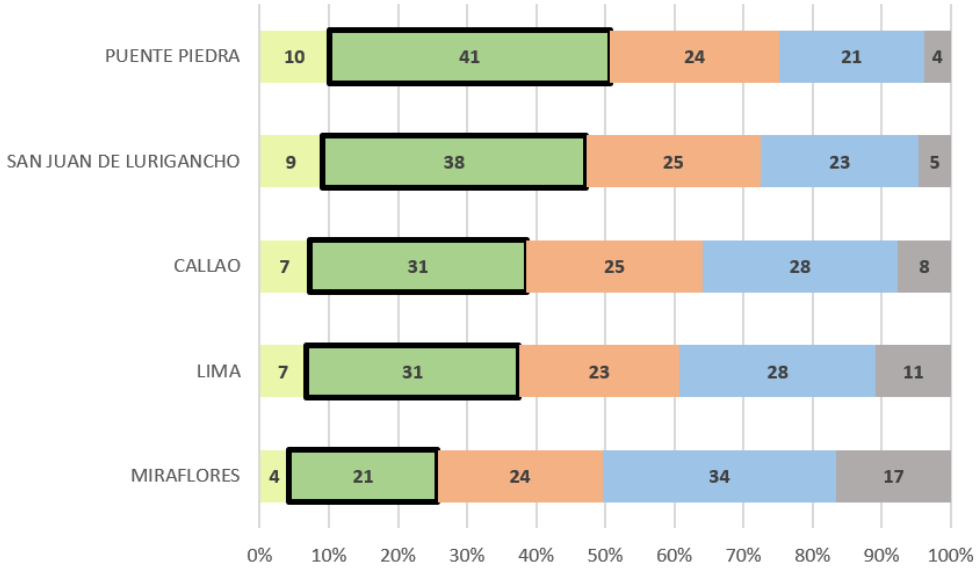
Age class below 5 years (source: INEI of 2013)

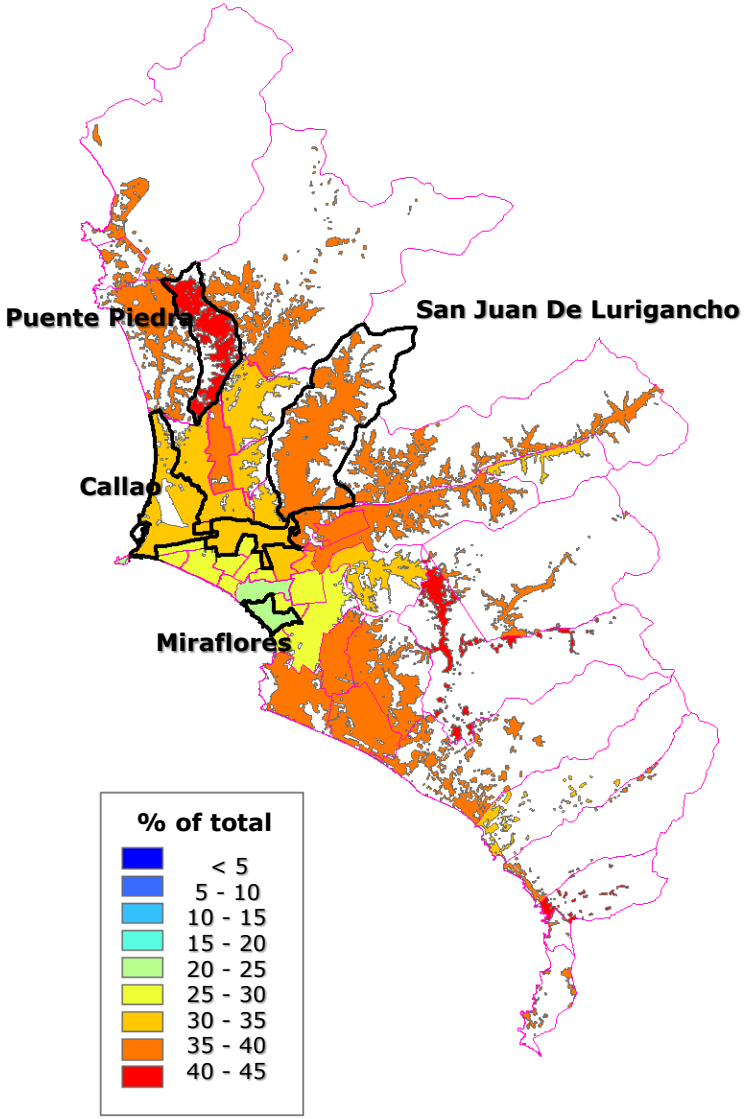




Population Structure (District of Lima, Peru)

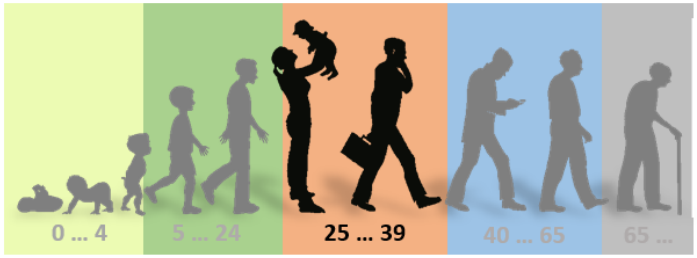
Age class below 5 – 24 years (source: INEI of 2013)

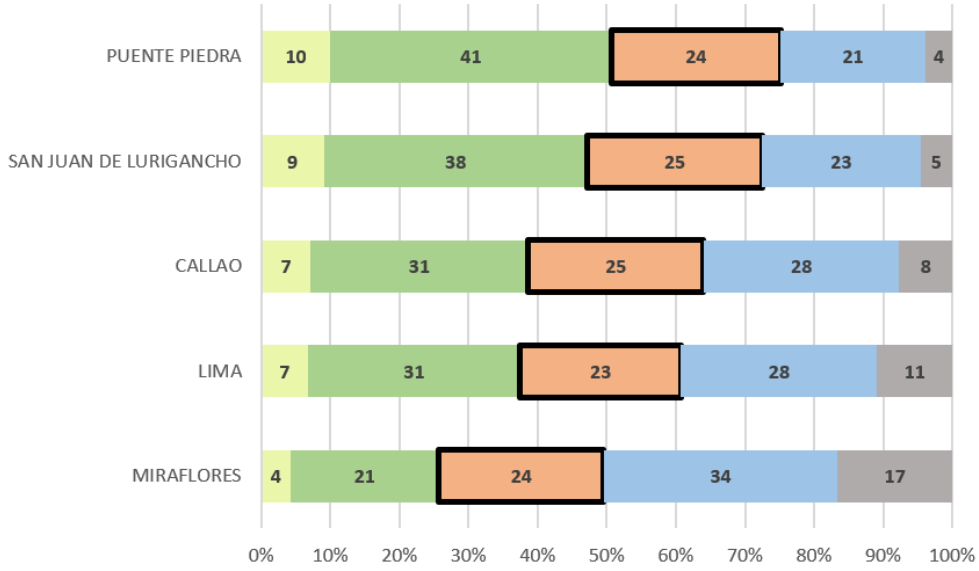


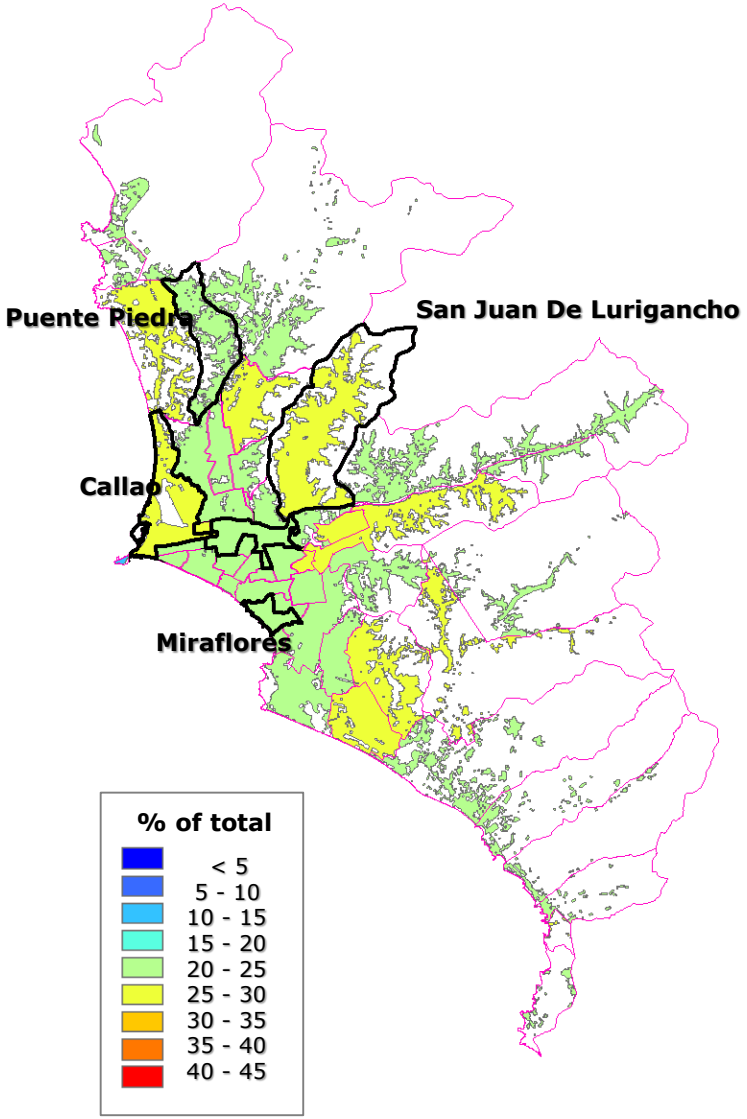


Population Structure (District of Lima, Peru)

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

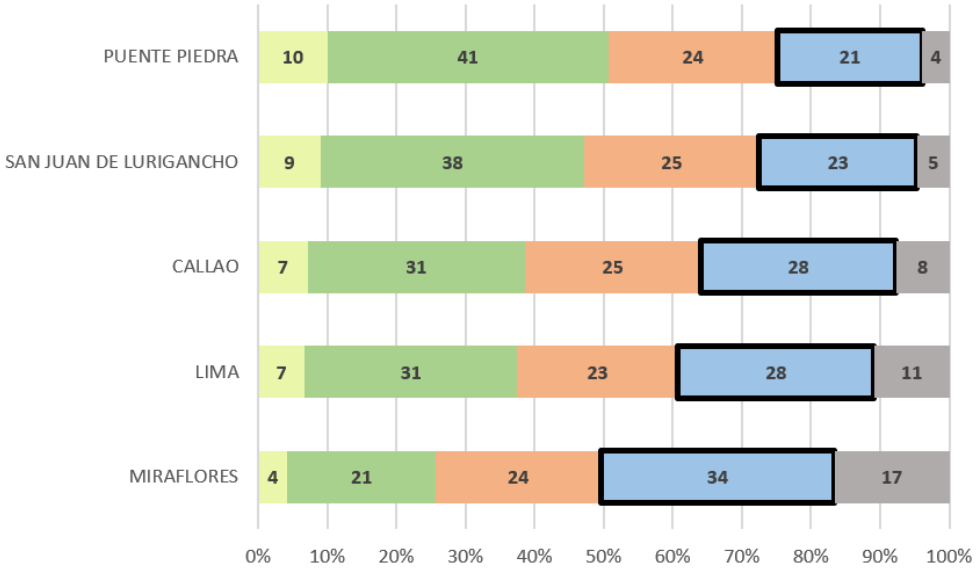


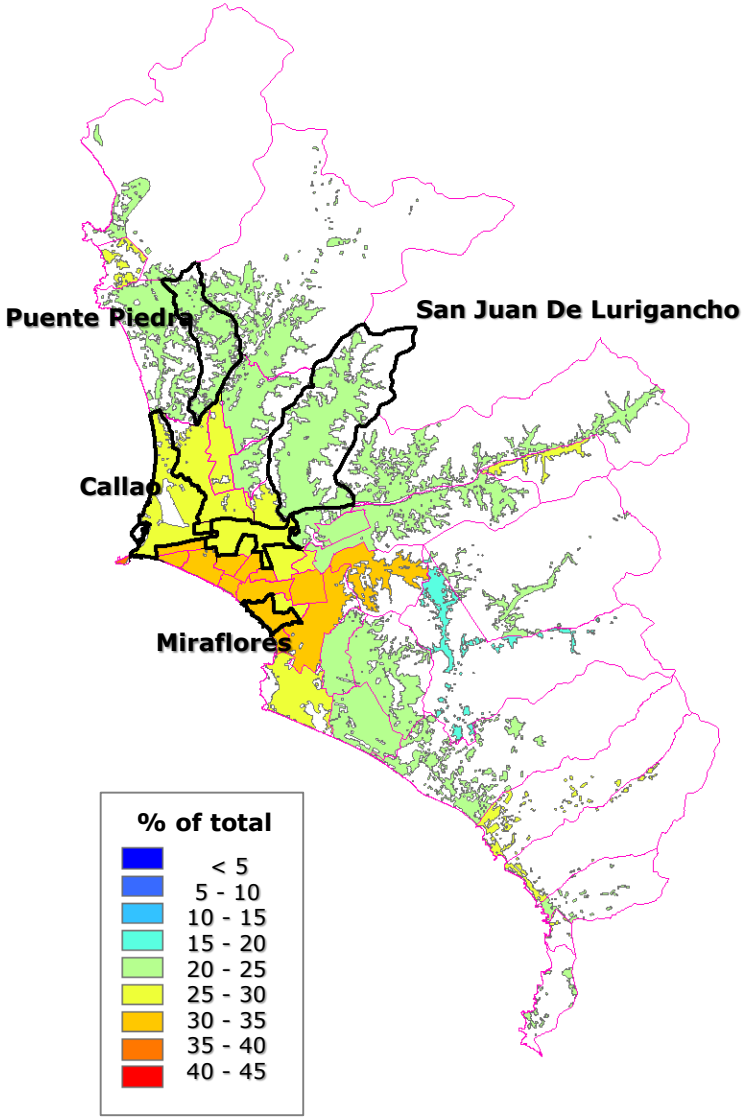




Population Structure (District of Lima, Peru)

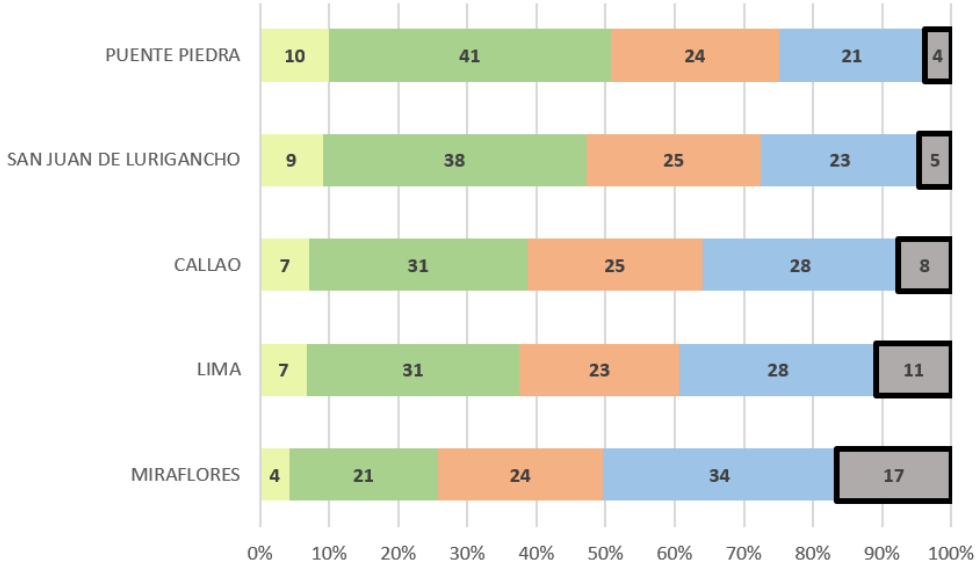
Age class below 40 – 64 years (source: INEI of 2013)

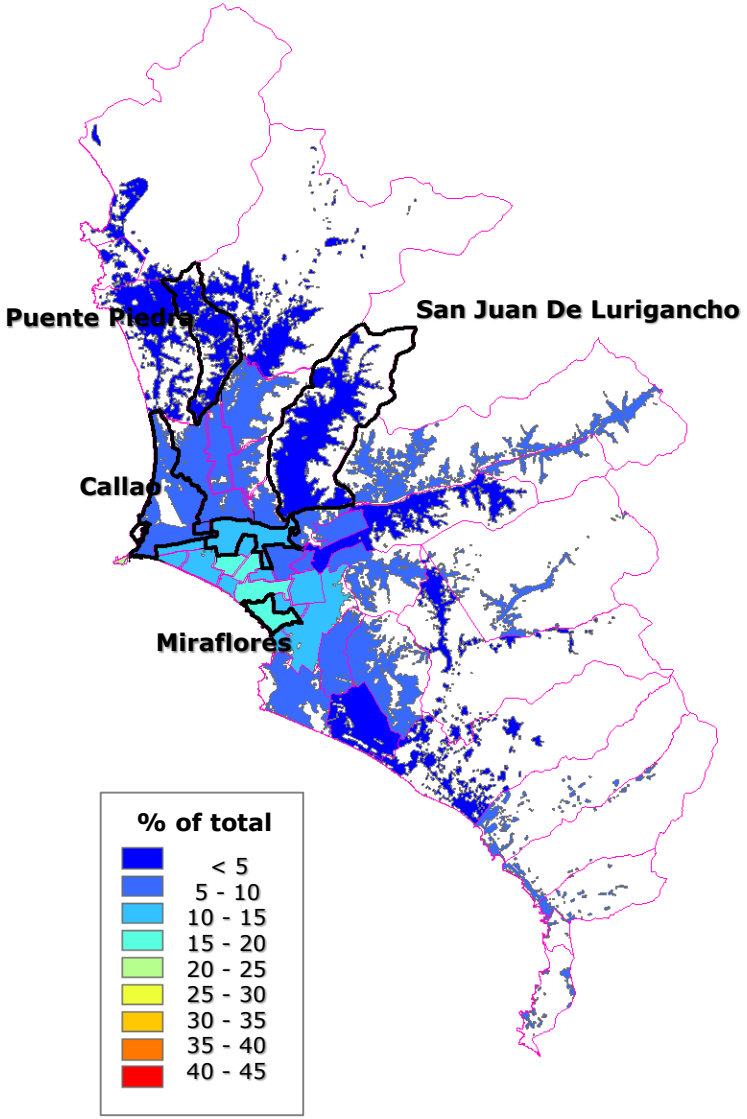




Population Structure (District of Lima, Peru)

Age class 65 years and olde (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

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