Mapping global urban boundaries from the global artificial impervious area (GAIA) data

Xuecao Li
College of Land Science and Technology
China Agriculture University
2020. 10. 09
Outline

1. Background
2. The GAIA data
3. Urban boundary delineation
4. Results and discussion
5. Summary
1. Background
Motivations

- **Current and future urbanization**
  - Urban population 55% today; 70% in 2050; 85% in 2100

- **Role of urban and urbanization**
  - Drivers of development and innovation
  - ~80% GDP; ~70% energy use

- **Dynamics and heterogeneity**
  - An improved understanding of urban environment

---

Zhou et al. (2018)
Interactions between urban and natural systems

Urban extent

Urban Heat Island

Vegetation Phenology

Building Energy Use

Public Health

Emission and Carbon Cycle
Urban boundary

- Basic units for urban studies
- 2D urban form
- Dynamics: process of urban expansion
Existing studies

- Density analysis combined with clustering \textit{(Vizzari et al., 2018)}
- Land use entropy model with Kriging interpretation approach \textit{(Hu et al., 2015)}
- Kernel density combining wavelet transform \textit{(Peng et al., 2016)}
- Density of urban infrastructures and population \textit{(US Census Bureau)}
- NTL derived urban boundaries \textit{(Zhou et al., 2018)}

\begin{itemize}
  \item Focus on local scale (e.g., city)
  \item Urban-rural transactional regions
\end{itemize}
2. The GAIA data
Mapping of global annual urban extent dynamics

Highlights:
- All modules complied on GEE
- Can be updated annually in time
- Can be applied to other satellite data (e.g., Sentinel)

Gong et al. (2020)
GAIA: Global Annual Impervious Area

1- Shanghai  2- Beijing  3- Karachi  4- Istanbul  5- Dhaka
6- Tokyo  7- Moscow  8- Manila  9- Tianjin  10- Mumbai

Resolution: 30m  
Source: Tsinghua University
Gong et al. (2020)
Improved mapping approach in arid areas

- Primary dataset: Landsat surface reflectance data (i.e., TM, ETM+, and OLI)
- Ancillary dataset: VIIRS nighttime light (NTL) data & Sentinel-1 GRD data
- Key: introduce a potential urban mask using NTL and Sentinel data
Improved mapping approach in arid areas
3. Urban boundary delineation
Overall framework

- **Region:** global
Kernel density map

- aggregate 30m GAIA data to 1km as the percentage of impervious surface area
- generate the kernel density (KD) map based on the ISA results (bandwidth: 5km)

More smoothed surface in urban domain
Boundary (rough)

- macro-scale (kernel density >20% as urban) (1km)
- micro-scale (neighborhood density; densities larger than 20% as urban; looply run for three times; 11x11 Window ~ 1km) (30m)
- merge derived urban boundaries from these two results
Boundary (detail) & Post-processing

- focus on urban fringe areas (using morphological method; 7x7 window);
  - (1) dilation (merge urban pixels if they are close)
  - (2) erosion (erode the dilated regions)

- identify different objects
  - (1) remove smaller urban clusters (<1km²)
  - (2) derive the boundary (raster -> shape file)
  - (3) remove small holes
4. Results and discussion
Compare with NTL derived results

NTL: urban extent map derived from DMSP/OLS NTL data (Zhou et al., 2018)

Dallas, TX, US (150km x 150km)  GUB: global urban boundary  More details can be revealed in GUB
Compare with NTL derived results

NTL: urban extent map derived from DMSP/OLS NTL data (Zhou et al., 2018)

Beijing, China (150km x 150km)  GUB: global urban boundary  More details can be revealed in GUB
Interpreted Results: from Landsat images (Wang et al., 2012)

Shenyang, China (60km x 60km) Good agreement
Compare with interpreted results

Interpreted Results: from Landsat images (Wang et al., 2012)

Wuhan, China (60km x 60km) Good agreement

(a) 1990 2000 2010 (b) A B

Interpreted GUB

(a) 1990 2000 2010 (b) A B

Wuhan, China (60km x 60km) Good agreement
Area comparison at the national scale

- Each dot represents the delineated urban boundary.
- In China: slightly overestimated than interpreted results.
- In US: slightly underestimated than interpreted results.
- GUB: consistent mapping approach and definitions.
Change of urban boundaries

Changsha, China

The mapping approach can well capture the trend of urban extent dynamics
Change of urban boundaries

The mapping approach can well capture the trend of urban extent dynamics
Urban boundary in different cities

- Las Vegas, US
- Edmonton, Canada
- Madrid, Spain
- New Delhi, India
- Buenos Aires, Argentina
- Lagos, Nigeria
- Bangkok, Thailand
- Xi'An, China

Underneath: Google Earth High Resolution Image
Global pattern of urban clusters

Urban Size: the area of delineated urban clusters

US has larger urban clusters than China
Area – rank relationship

Included clusters: urban area > 1000 km²

- Zip’s law relationship
- From 1990 to 2018, increased number of large urban clusters
- Same rank order with notably increased urban areas over past decades
Ratio: ISA / Urban Area

US – Dallas (150km x 150km)

Google Earth Image  ISA map  Urban Boundary (before remove small holes) (after remove small holes)

3002 km²  3988 km²  4309 km²

Ratio: ISA / Urban Area = 69%
Ratio: ISA / Urban Area

- Ratio: ISA/Urban, from 53% to 60%, showing a consistent increasing trend from 1990 to 2018.
- Low ISA ratio: smaller urban cluster; Larger ISA ratio: larger urban clusters
5. Summary
Summary

- Long term and fine resolution urban clusters
- The delineated boundary agrees well with the urban extent
- Serve as basic spatial unit and support for global studies
Thank You