National Aeronautics and Space Administration

Introduction to the Applications of Population Grids

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UN Sustainable Development Solutions Network

April 06, 2021

Center for International Earth Science Information Network
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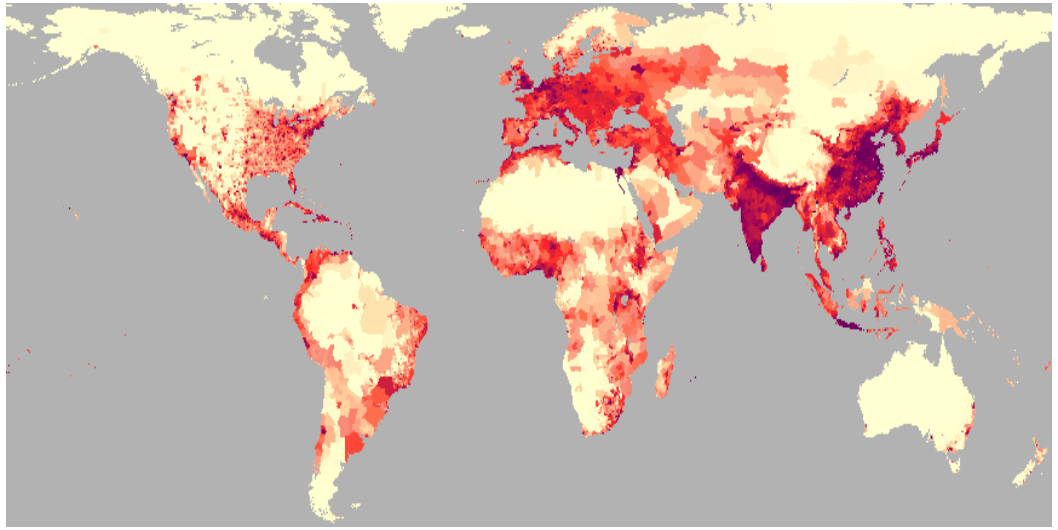
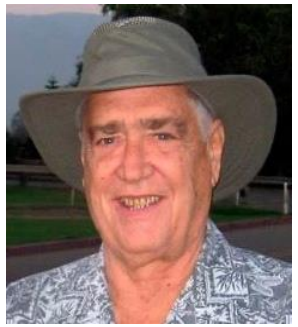
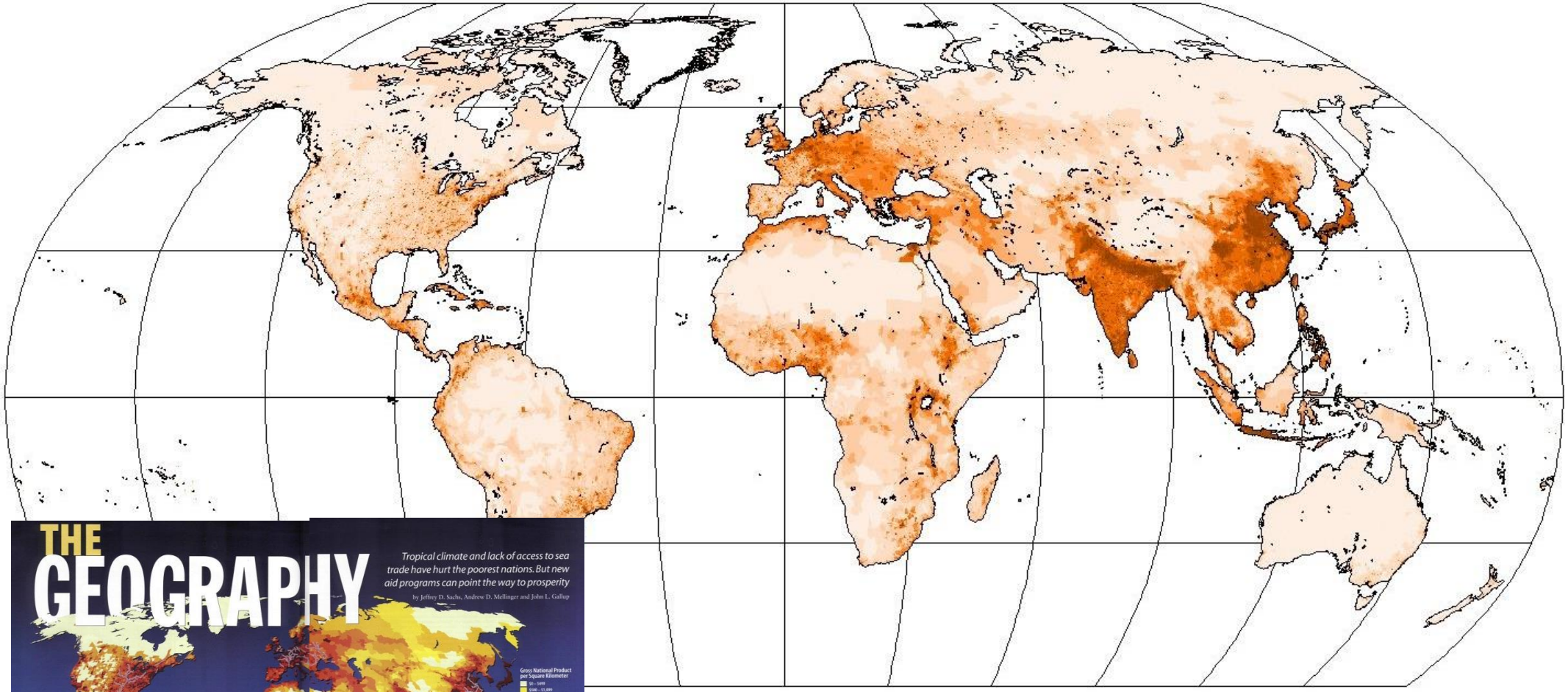
Original Gridded Population of the World Dataset

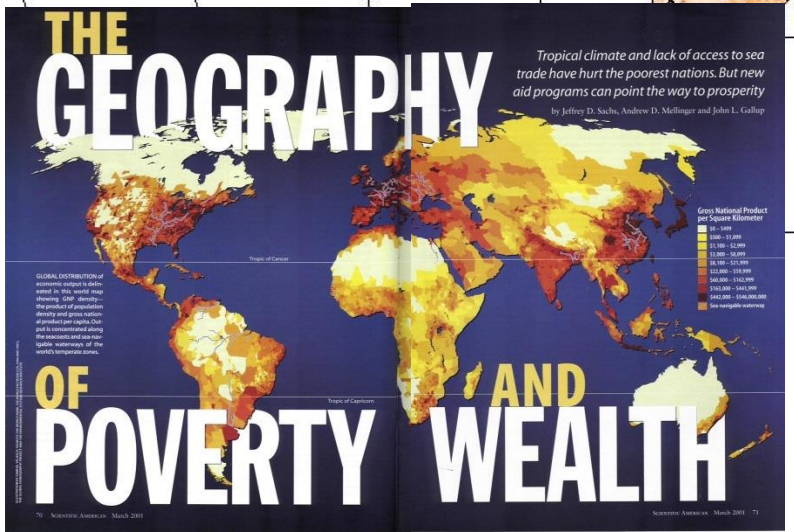
- Created in 1994-95
  - Collaboration with NCGIA (Waldo Tobler and Uwe Deichmann)
  - 19,000 administrative units used
  - Estimated 1994 populations; total population of 5.6 billion
  - 5' x 5' lat-lon spherical quadrilaterals, 6.7 million cells
  - Unsmoothed and smoothed versions (Tobler's pycnophylactic algorithm)
  - Regional and global coverages





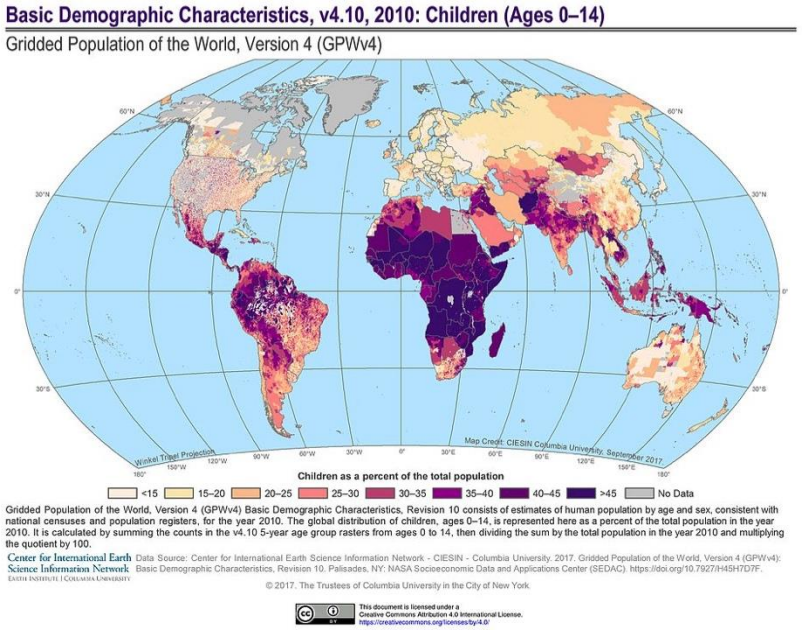
Gridded Population of the World – Version 2

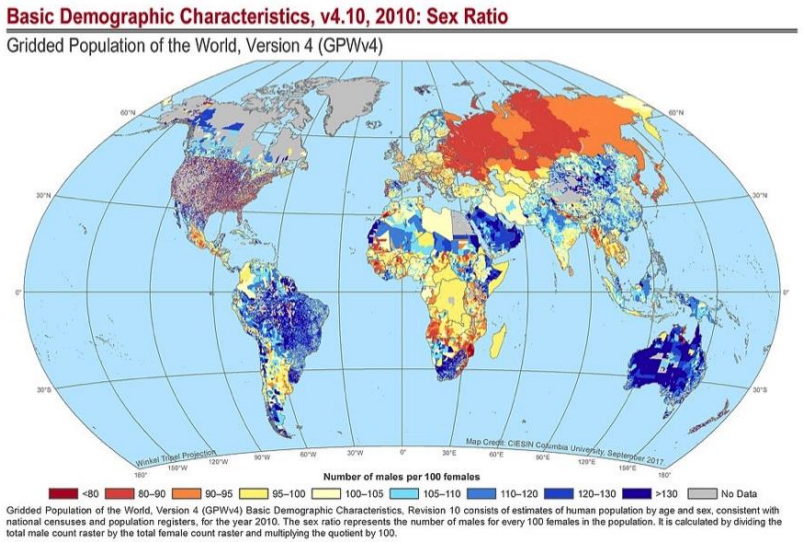


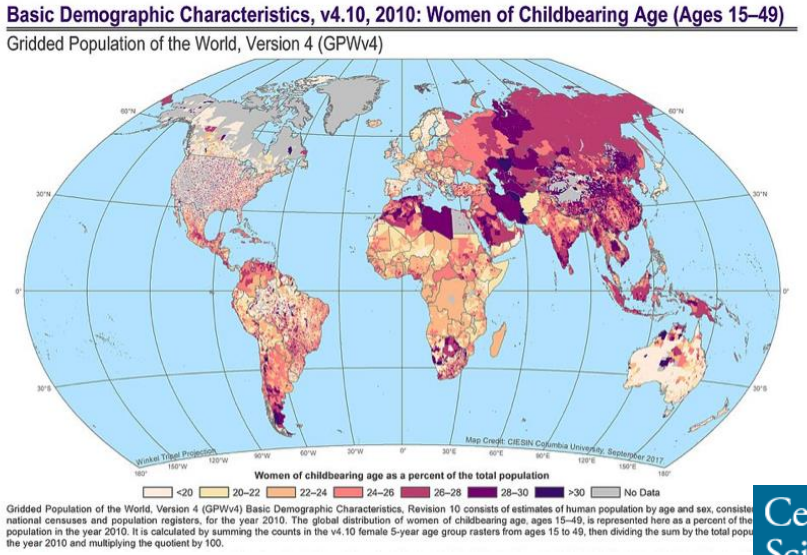


J. Sachs *et al.*, 2001. The Geography of Poverty and Wealth. *Scientific American*, Vol. 284 (3, March), pp. 70-5

GPWv4.11, Population by Age Group & Gender, 2010





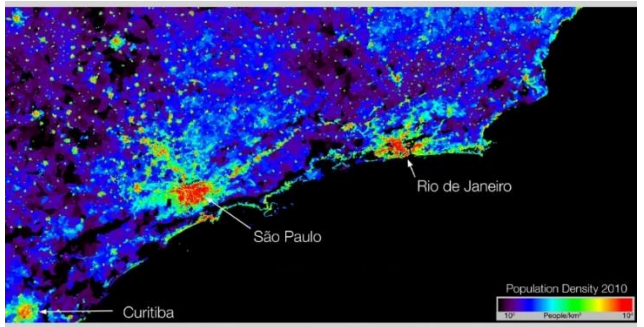


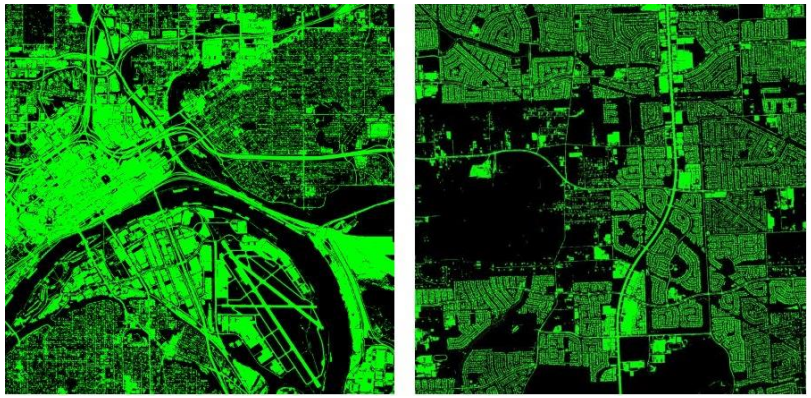
GPWv4.11 includes a dataset on Basic Demographic Characteristics with gridded estimates of population by age groups and gender for 2010.

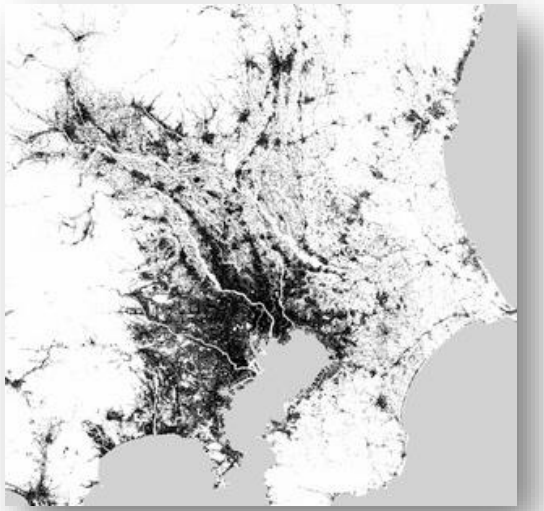
http://sedac.ciesin.columbia.edu/data/collection/gpw-v4/sets/browse

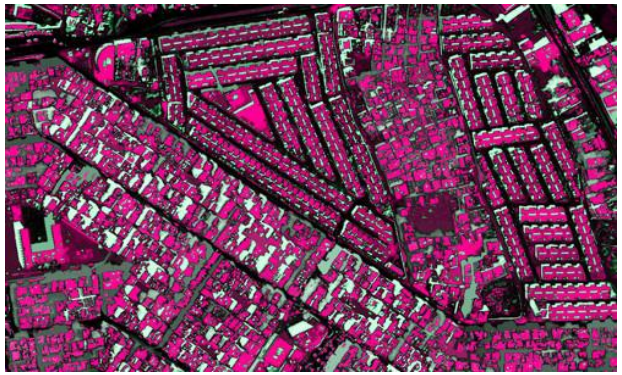
New Sources of Data for Mapping Human Settlements, Infrastructure, and Population

- Night-Time Lights (DMSP >1 km → VIIRS ~750 m)
- Landsat (~30 m)
- Radar (~12 m)
- High Resolution Imagery (< ~3 m resolution)



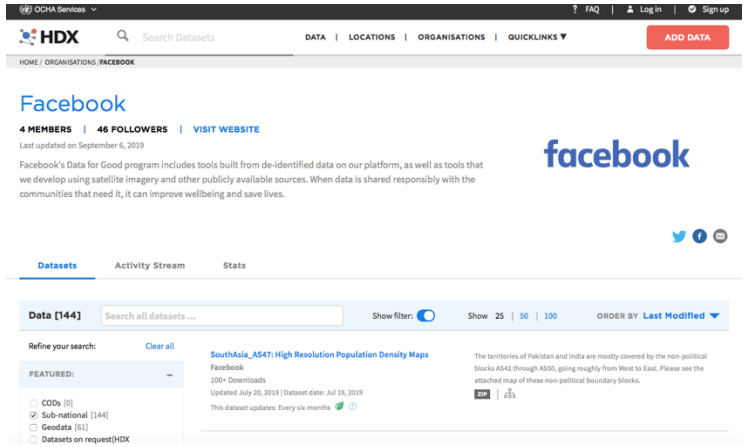




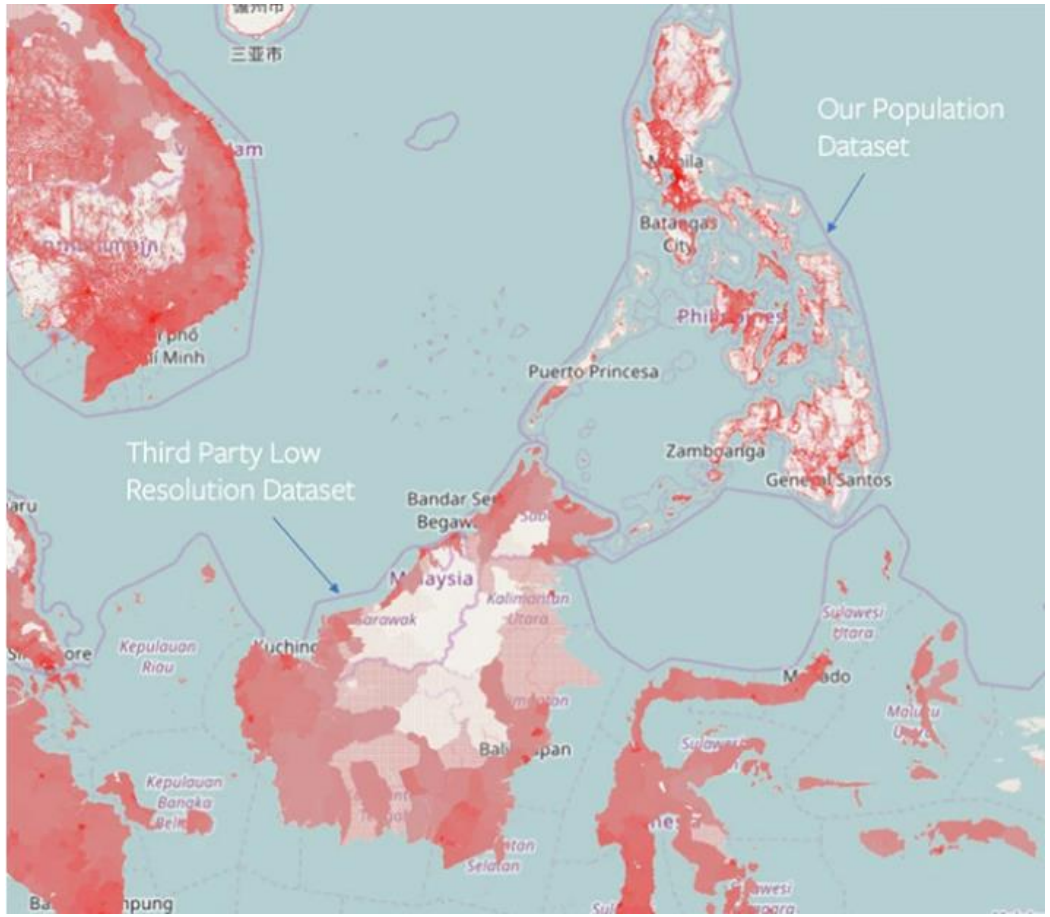


High Resolution Settlement Layer from Facebook

- Result of a collaboration between Facebook, CIESIN, and the World Bank
- Originally motivated by the desire to optimize Internet access in rural areas
- Further development driven by humanitarian needs identified by the IFRC and others

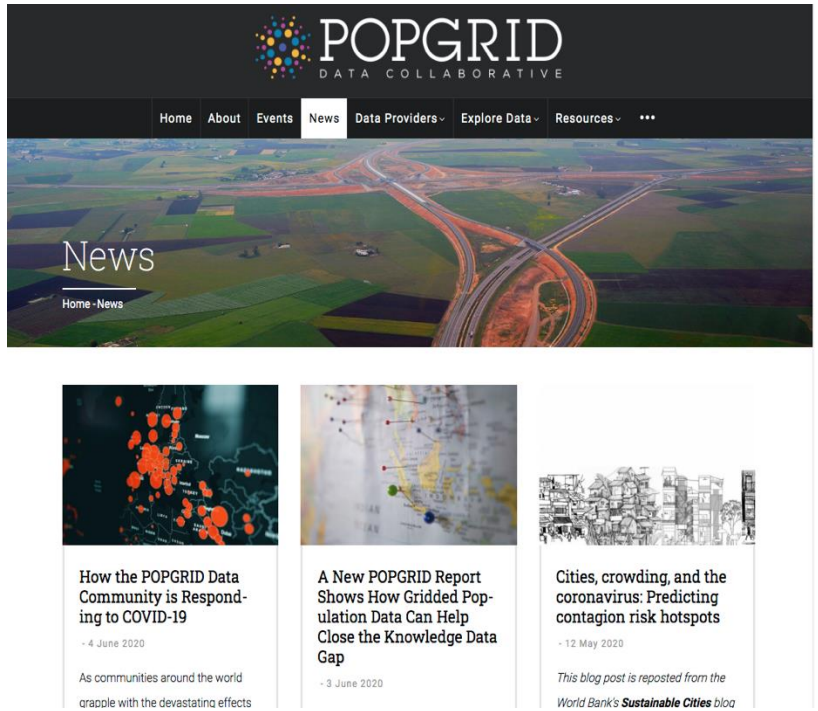


https://data.humdata.org/organization/facebook

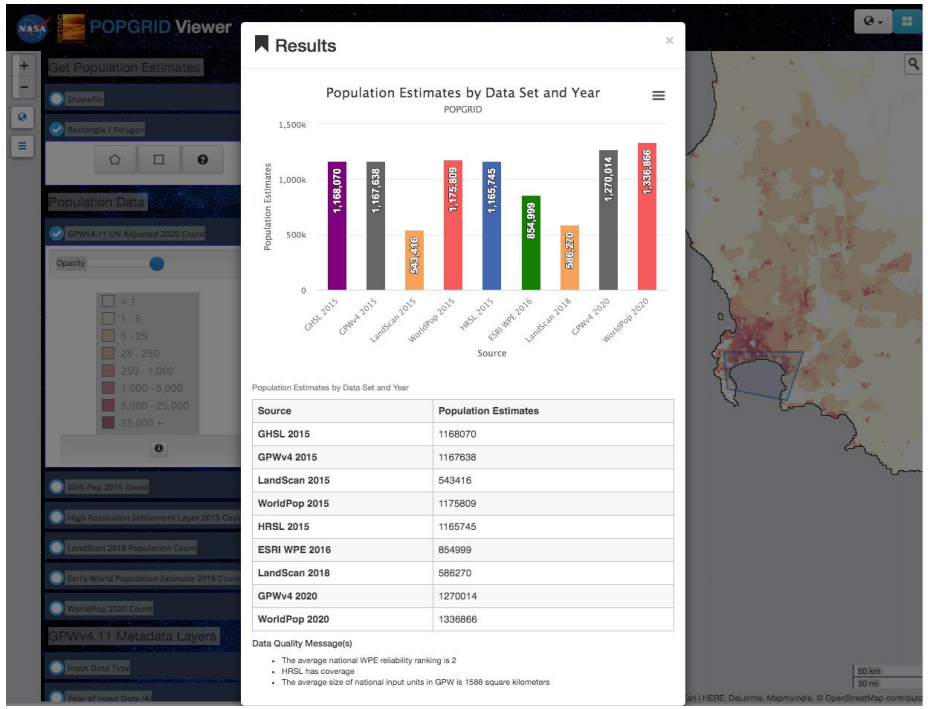


https://tech.fb.com/ai-powered-maps-help-vaccination-campaigns/

POPGRID Website and Viewer



https://www.popgrid.org/



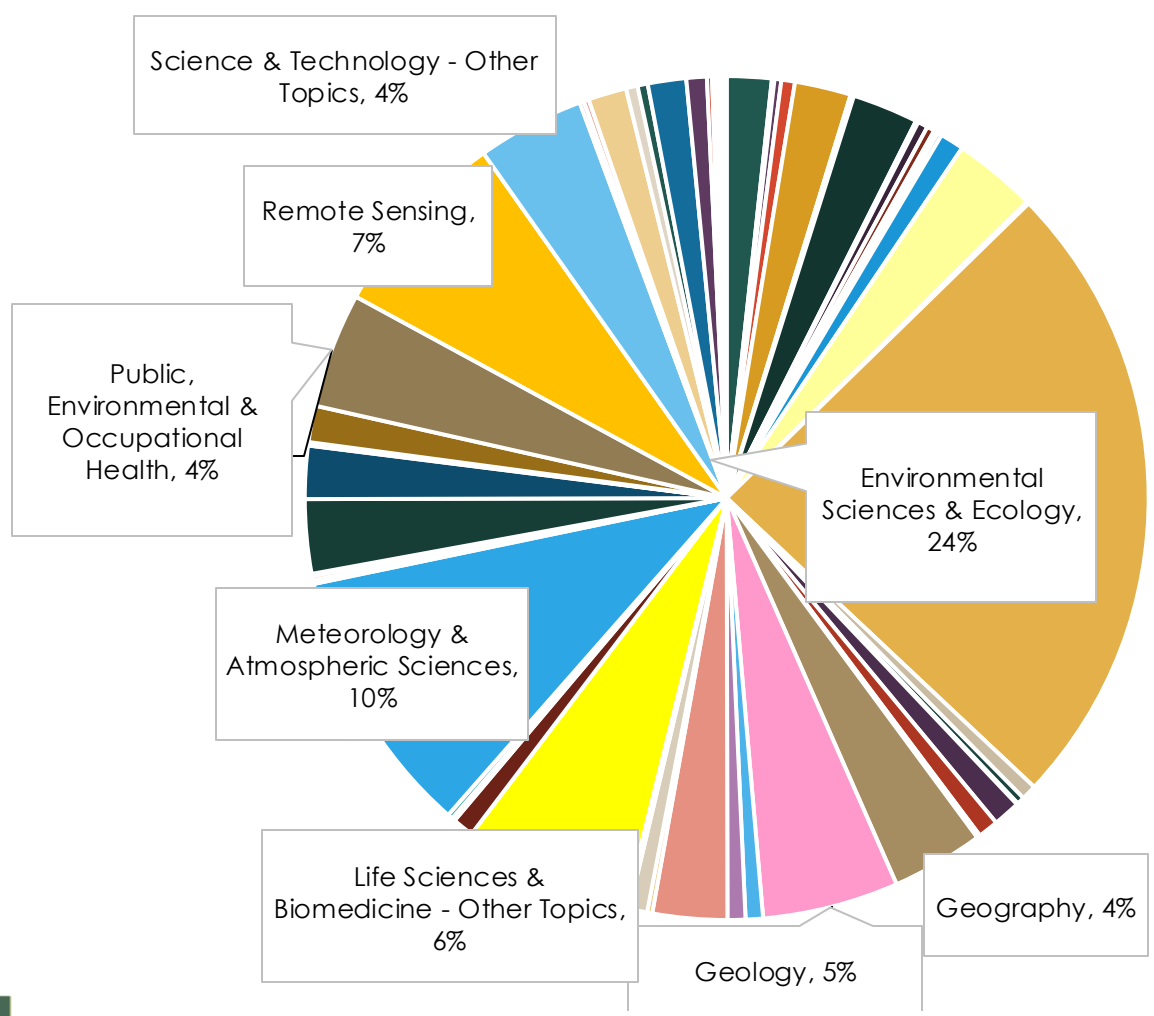
https://sedac.ciesin.columbia.edu/mapping/popgrid/

Applications of SEDAC's Gridded Population Data in Scientific Literature

- More than 3,300 citations of GPW versions in SEDAC's citation database
- More than one-fourth of these citations also cite remote sensing data

https://sedac.ciesin.columbia.edu/citations-db

63 Subject Areas of Journals with Articles Co-Citing SEDAC Data with Remote Sensing Data, 2007-2016



- Agriculture
- Area Studies
- Astronomy & Astrophysics
- Biochemistry & Molecular Biology
- Biodiversity & Conservation
- Biotechnology & Applied Microbiology
- Business & Economics
- Cell Biology
- Computer Science
- Demography
- Education & Educational Research
- Emergency Medicine
- Endocrinology & Metabolism
- Energy & Fuels
- Engineering
- Entomology
- Environmental Sciences & Ecology
- Evolutionary Biology

Downs, Chen, & Schumacher, AGU, 2017

Recent Citations: *Science*

Science Impact Factor (2019): 41.845

- Lau, W. W. Y., Shiran, Y., Bailey, R. M., Cook, E., Stuchtey, M. R., Koskella, J., . . . Palardy, J. E. Evaluating scenarios toward zero plastic pollution. *Science*, First release, 23 July.
  - Uses **GPW v4.11** in combination with HydroSHEDS to assess population within 1 km of water and to delineate urban from rural areas (using European Commission definition). HydroSHEDs is based on SRTM data.

Table S3: Estimated populations living in proximity to rivers or coastal waters.

	Number of people living in proximity to water		Proportion of population living in proximity to water	
Archetype	< 1 km	> 1 km	< 1 km	> 1 km
HI-U	387,364,176	502,326,123	43.5%	56.5%
HI-R	139,551,400	200,098,923	41.1%	58.9%
UMI-U	738,055,814	953,720,947	43.6%	56.4%
UMI-R	333,681,550	481,968,707	40.9%	59.1%
LMI-U	957,825,466	1,115,472,519	46.2%	53.8%
LMI-R	340,003,878	470,101,017	42.0%	58.0%
LI-U	91,908,375	136,868,144	40.2%	59.8%
LI-R	159,418,874	278,735,508	36.4%	63.6%

https://doi.org/10.1126/science.aba9475

- Lecocq, T., Hicks, S. P., Van Noten, K., van Wijk, K., Koelemeijer, P., De Plaen, R. S. M., . . . Xiao, H. Global quieting of high-frequency seismic noise due to COVID-19 pandemic lockdown measures. *Science*, First release, 23 July.
  - Uses **GPW v4.11** to distinguish seismic measurements in dense vs. sparse areas.

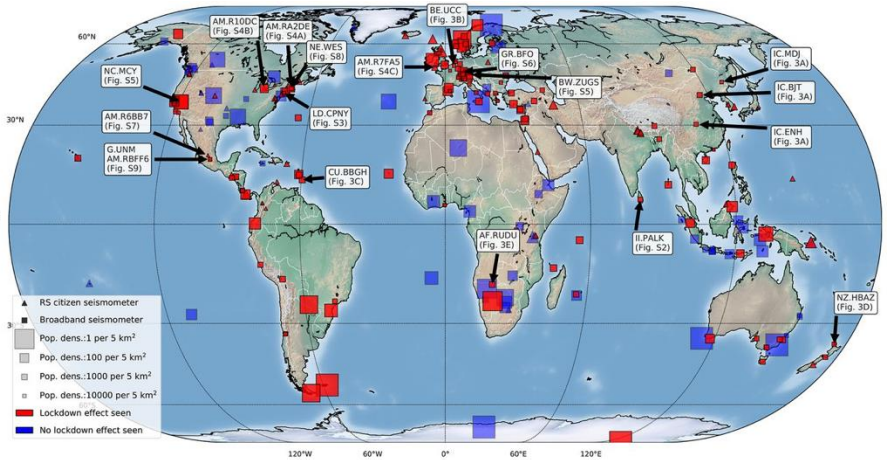


Fig. 1 Worldwide seismic station locations. Locations of the 268 global seismic stations with usable data (e.g., no long data gaps, working sensors) we analyzed. Lockdown effects are observed (red) at 185 out of 268 stations. Symbol size is scaled by the inverse of population density (28) to emphasize stations located in remote areas…

https://doi.org/10.1126/science.abd2438

Recent Citations: *Nature Communications*

- Boulange, J., Hanasaki, N., Yamazaki, D., & Pokhrel, Y. (2021). Role of dams in reducing global flood exposure under climate change. *Nature Communications*, 12(1), 417.
  - Uses **GPWv4.11** for population exposure estimates
  - Also uses Global Reservoirs and Dams (**GRaND**) database (but not necessarily SEDAC's version)

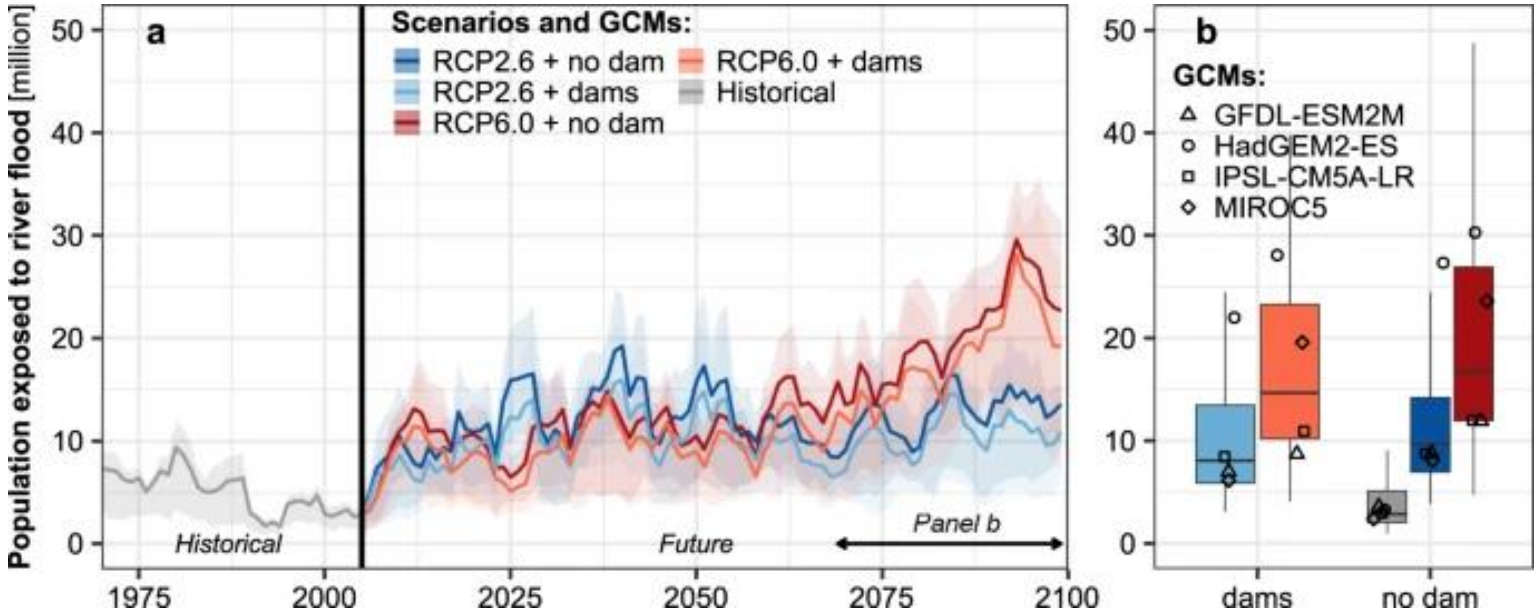


Fig. 1: Population exposure to the historical 100-year river flood (keeping population constant at 2010 level) downstream of dams
https://doi.org/10.1038/s41467-020-20704-0

nature communications Impact Factor (2019): 12.121

Recent Citations: *The Lancet*

- Watts *et al.* 2020. The 2020 report of The *Lancet* Countdown on health and climate change: responding to converging crises. Online First, 2 December.
  - Uses **GPWv4** in computing multiple health impact indicators including excess heat, wildfire risk, labor force impacts, and urban green space

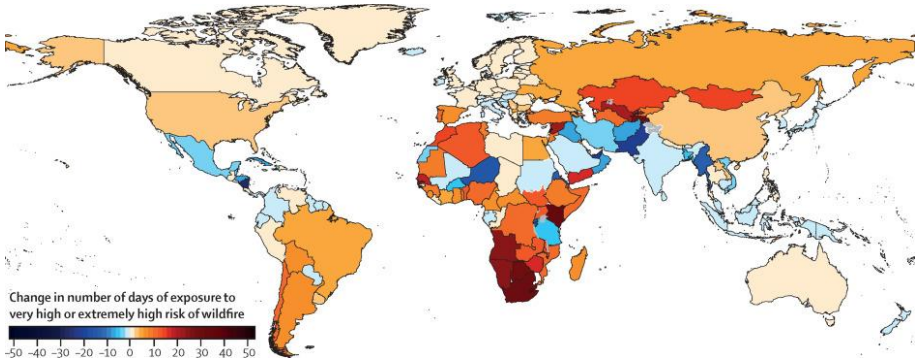


Figure 4. Population-weighted average changes in the number of days of exposure to very high or extremely high risk of wildfire in 2016–19 compared with 2001–04

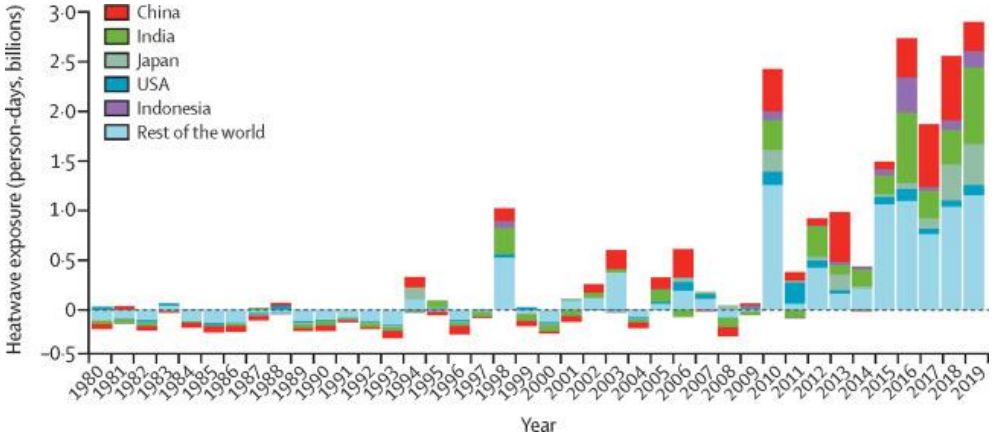


Figure 1. Change in days of heatwave exposure relative to the 1986–2005 baseline in people older than 65 years

https://doi.org/10.1016/S0140-6736(20)32290-X

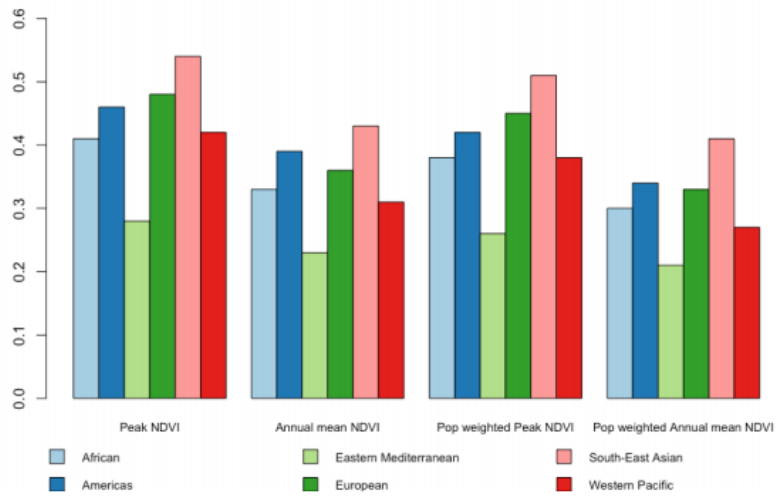


Figure 40: Urban Green Space by WHO Region.

Recent Citations: *The Lancet*

- Sartorius, B., Cano, J., Simpson, H., Tusting, L. S., Marczak, L. B., Miller-Petrie, M. K., . . . Pullan, R. L. (2021). Prevalence and intensity of soil-transmitted helminth infections of children in Sub-Saharan Africa, 2000–18: a geospatial analysis. *The Lancet Global Health*, *9*(1), e52-e60.
  - Uses **GPWv4.11** estimates for **children aged 5-14 years** to estimate population counts of infection and moderate-to-heavy infection by species

  https://doi.org/10.1016/S2214-109X(20)30398-3

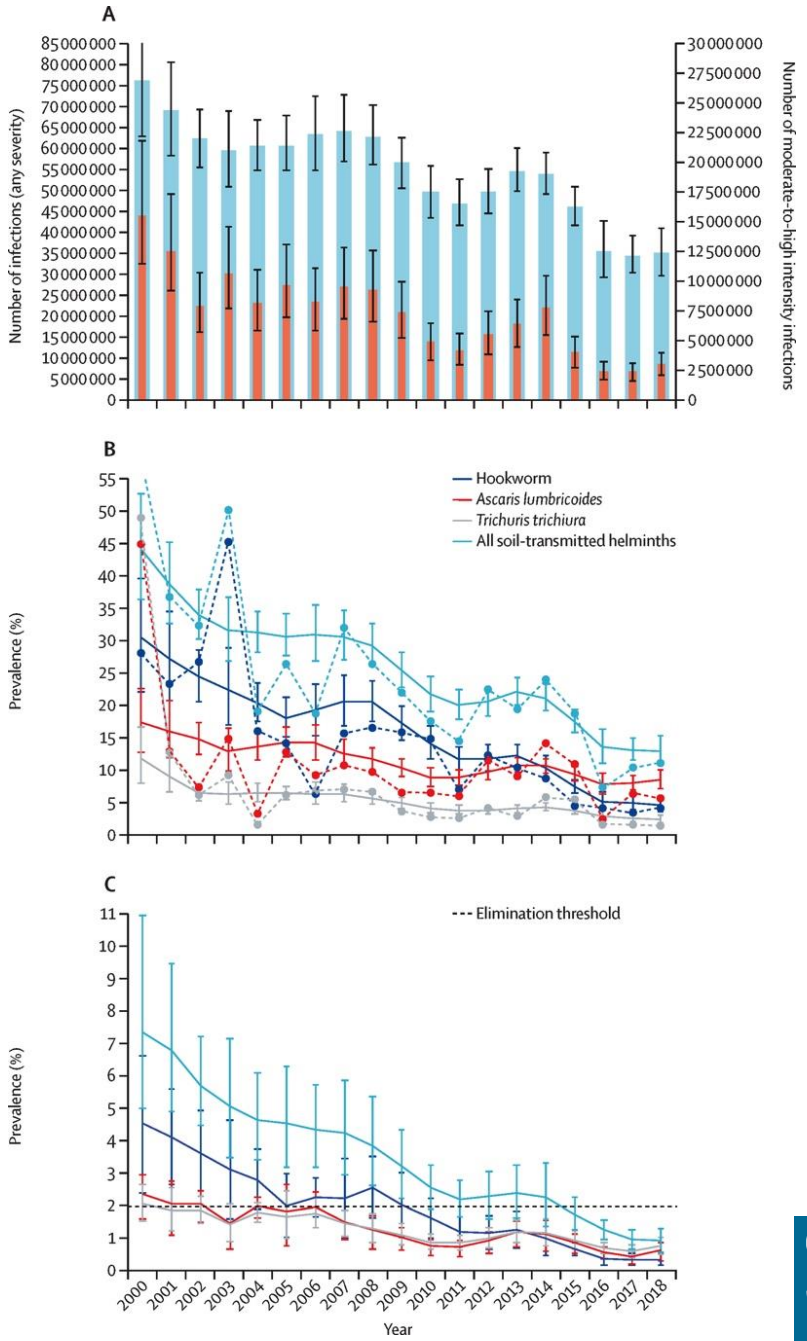
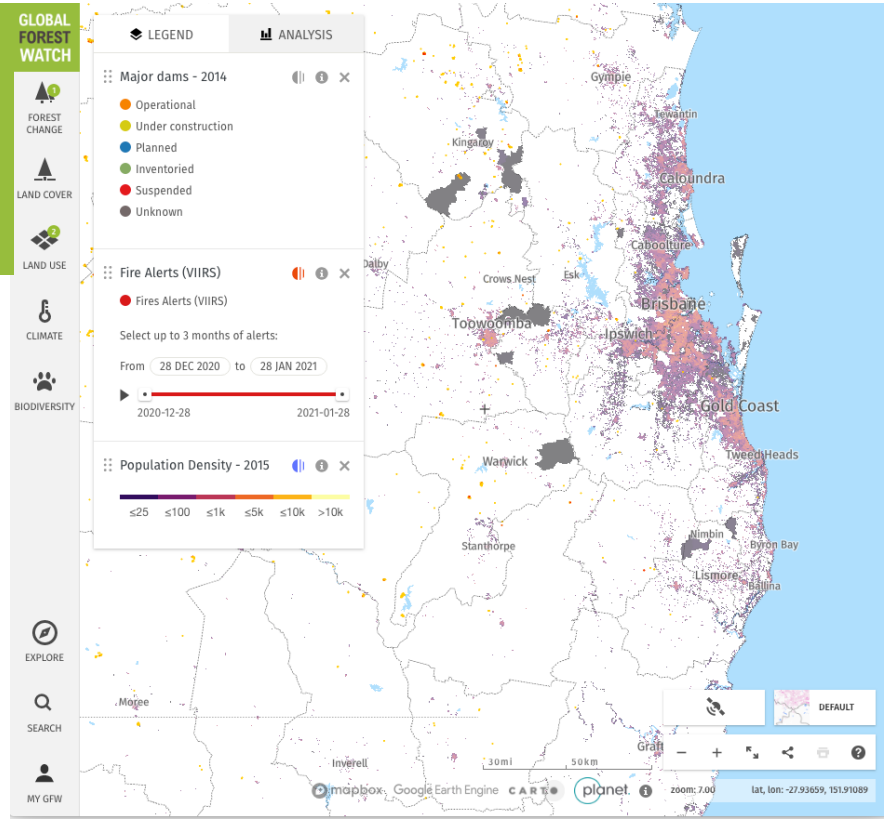
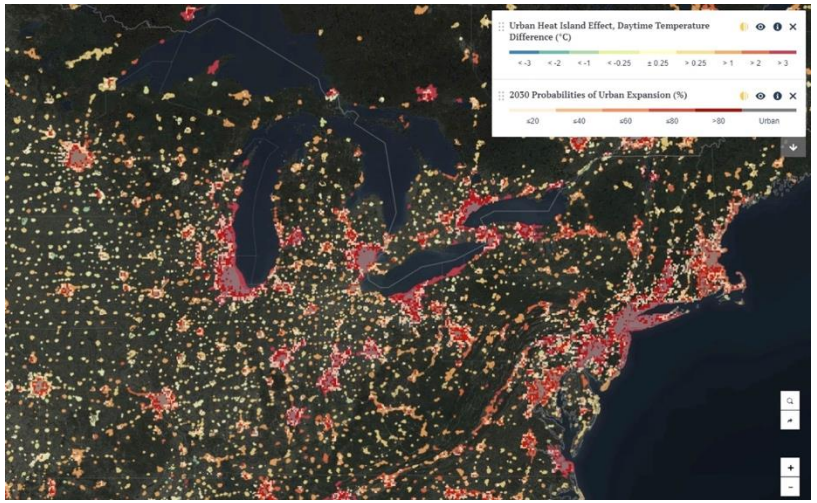


Figure 1. Prevalence of any soil-transmitted helminth infections (A) and of moderate-to-high intensity infections (B), and the absolute number of prevalent cases (C), in children aged 5–14 years in sub-Saharan Africa, 2000–18

SEDAC Data Reuse: Global Forest Watch and PREPdata



The Global Human Settlement Layer population (GHS-POP) data developed with the JRC, and Global Reservoir and Dam (GRaND) data are available as layers in the Global Forest Watch interactive map, in conjunction with other satellite data and imagery https://www.globalforestwatch.org/



- Partnership for Resilience and Preparedness (PREP)
  - Map-based, open data online platform for climate adaptation and resilience planning
  - Includes >4 data sets from SEDAC, including GPWv4, GRanDv1, GHSL-POP, and Global Roads Open Access Dataset (gROADS)

https://www.prepdata.org/explore

PARTNERSHIP FOR RESILIENCE &PREPAREDNESS

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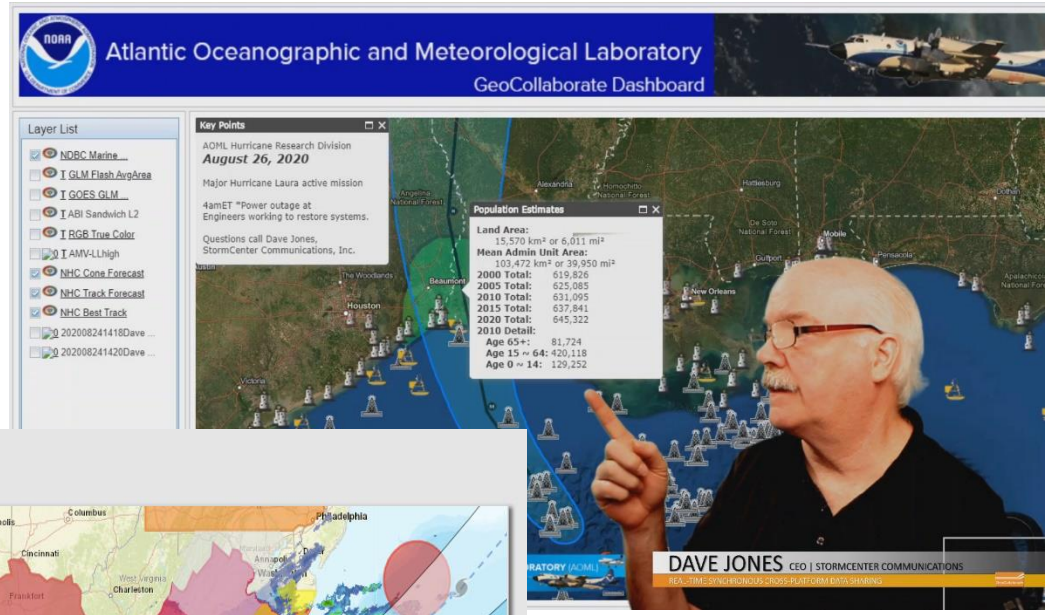
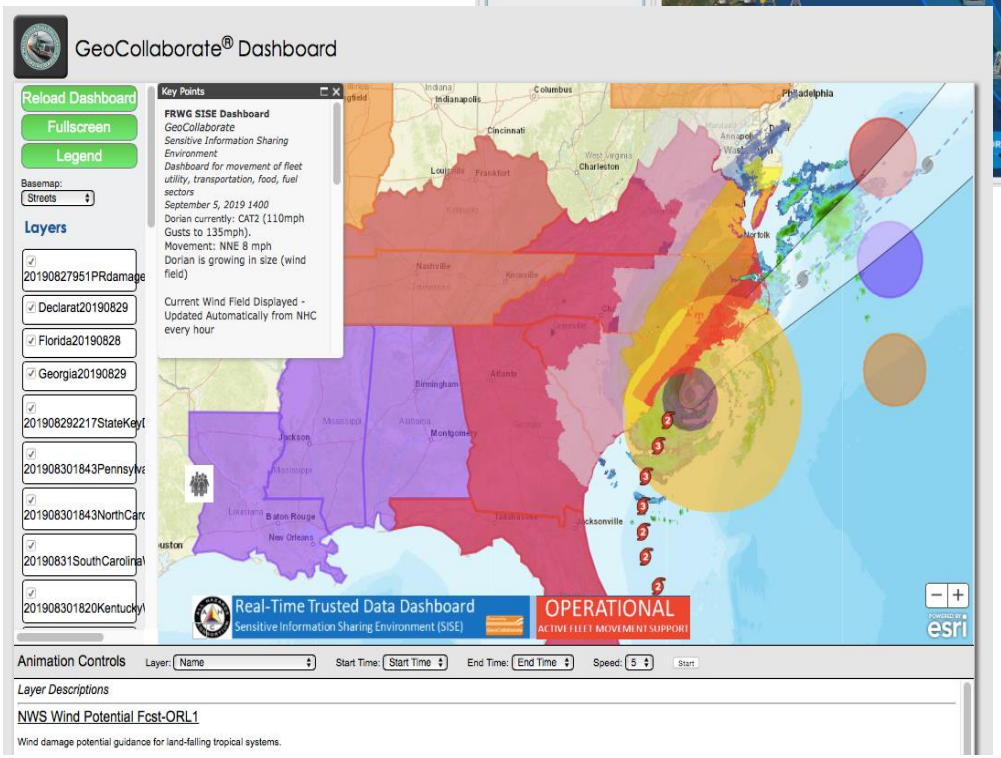
Use of the SEDAC Population Estimation Service in the GeoCollaborate Decision Support Tool

- Use open services to enable data and queries to be accessed via **existing** decision support systems
- Support flexible platforms that integrate and transform data from multiple sources into timely and usable information





https://frwg.geocollaborate.com/dashboard/

NASA's Applied Remote Sensing Training Program

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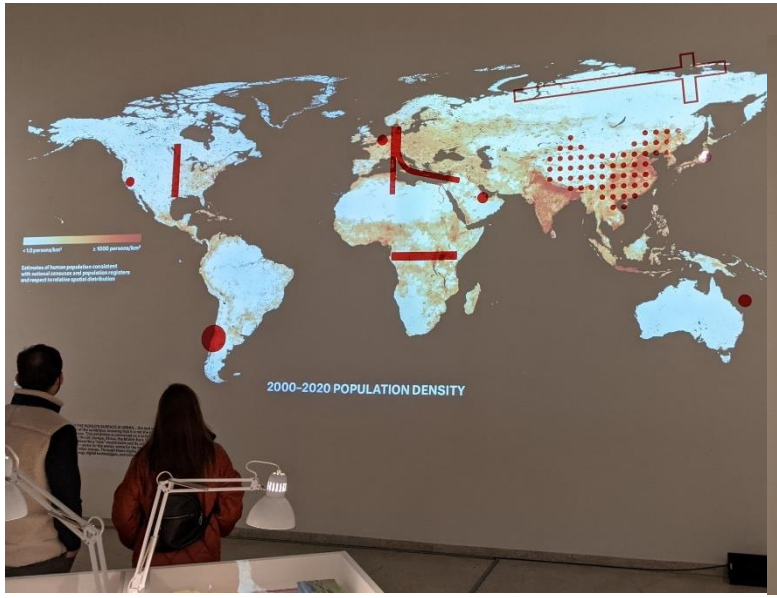
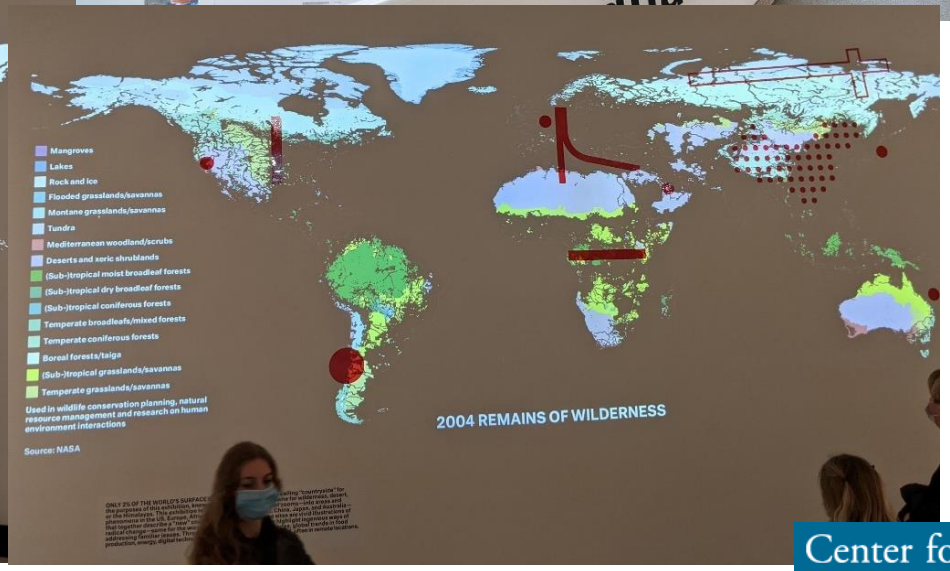
SEDAC Data Reuse: Informal Education

- Several SEDAC and NASA datasets featured prominently in "Countryside" Exhibit at the Guggenheim Museum through February 15, 2021
  - GPW, Human Footprint/Last of the Wild, gROADS, Nuclear Power Plants
  - Nighttime lights, land surface temp, etc.





GEO Focused on the Role of Earth Observations to Address the Sustainable Development Goals

- "Population distribution" and "Cities and Infrastructure Mapping" are important to indicators and decision making related to all 17 goals.

Alignments of the Goals with Specific Types of Earth Observations and Geospatial Information

GEO GROUP ON EARTH OBSERVATIONS
GI-18 Initiative

THE GLOBAL GOALS For Sustainable Development

Role of Fundamental Geospatial Data Layers in Assessing SDG Indicators

No.	Indicator
1.5.1	Number of deaths, missing persons and persons affected by disaster per 100,000 people
7.1.1	Proportion of population with access to electricity
9.1.1	Proportion of the rural population who live within 2 km of an all-season road
11.1.1	Proportion of urban population living in slums, informal settlements or inadequate housing
11.2.1	Proportion of population that has convenient access to public transport
11.3.1	Ratio of land consumption rate to population growth rate
11.6.2	Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (pop. weighted)
11.7.1	Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities

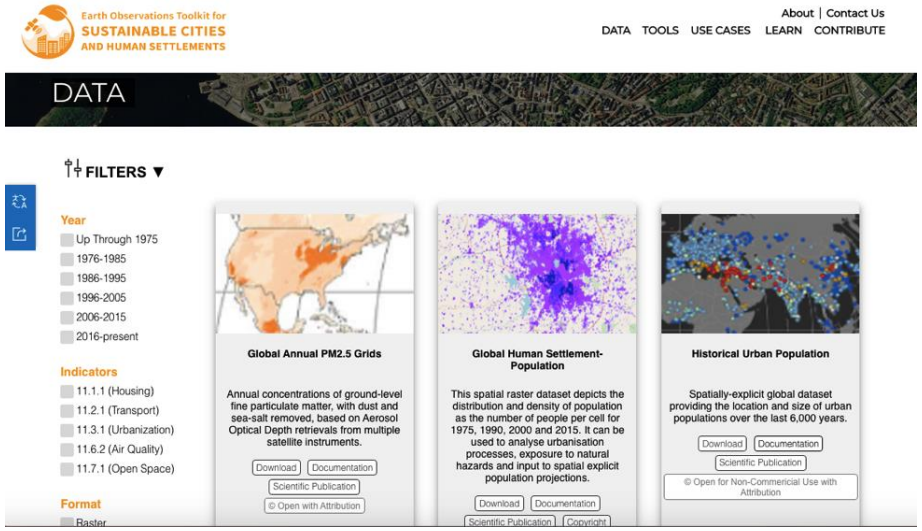
Many SDG indicators directly require fundamental population, settlement, and infrastructure data.

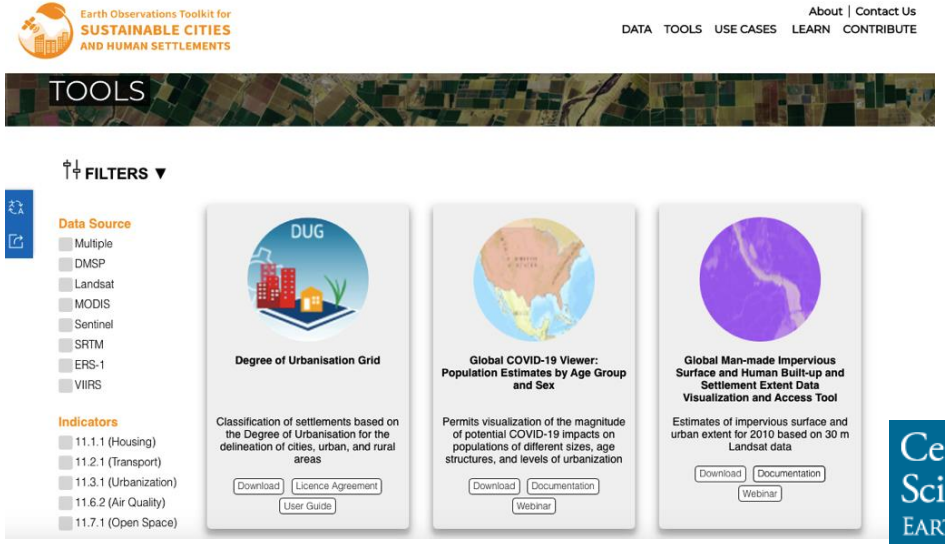
- Consistency in methods between data is therefore important.
- Choice of datasets has implications for indicator accuracy and consistency.

Earth Observations Toolkit for Sustainable Cities and Human Settlements

- Collaboration between UN-Habitat and GEO EO4SDGs
- More than 12 SEDAC datasets and 3 SEDAC interactive tools are featured
- Aimed at urban and national planners and statisticians
- Launch event on January 21, 2021 at UNSD side event

https://eo-toolkit-guo-un-habitat.opendata.arcgis.com/





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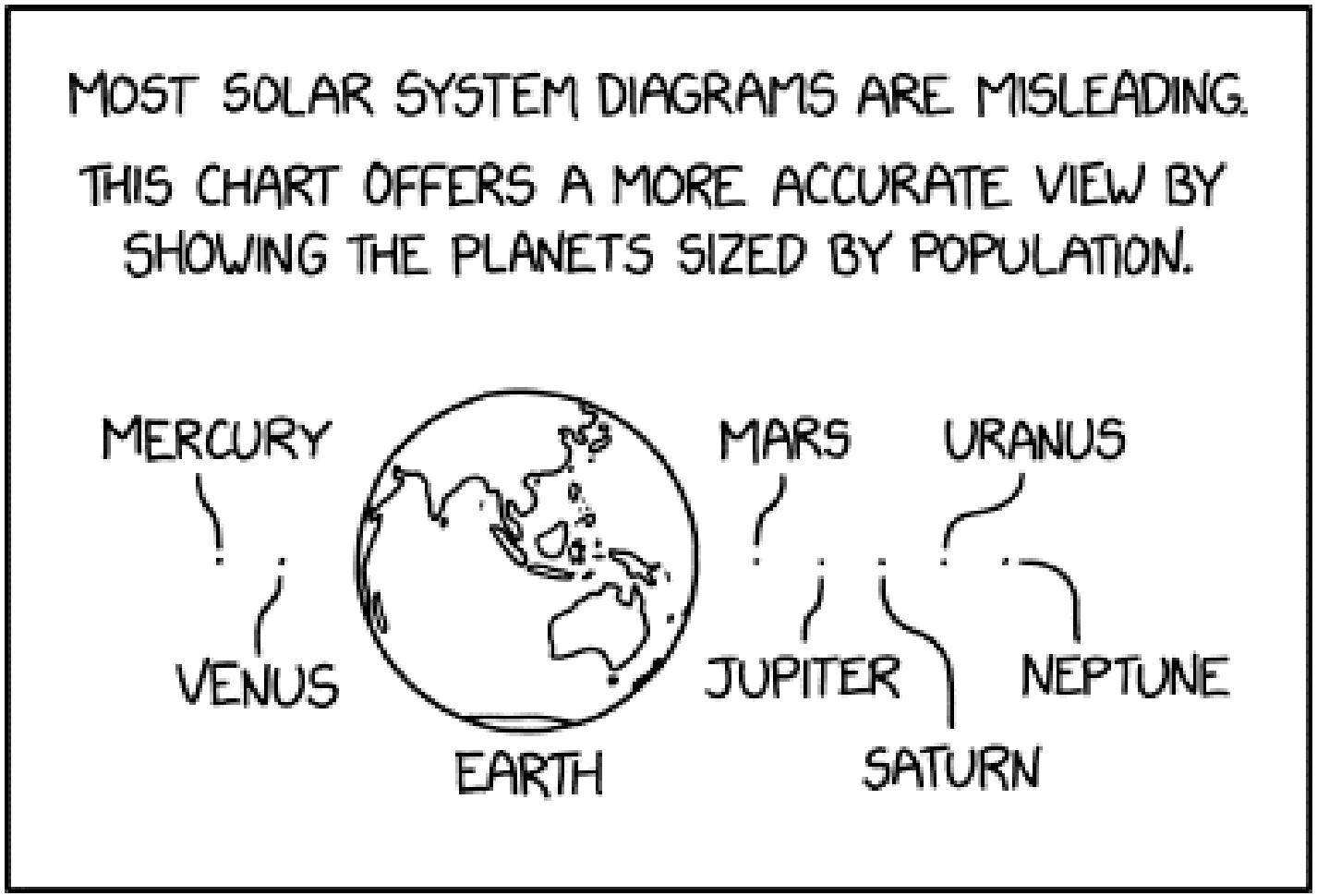
Population Makes a Difference!



https://xkcd.com/2439/

Measuring development progress: Proportion of the rural population who live within 2 km of an all-season road (SDG 9.1.1)

Linda Pistolesi and James Gibson, CIESIN

April 6, 2021

Learning Objectives

By the end of this session, you will be able to…

1. Describe Indicator 9.1.1 and how it is measured
2. Identify the geospatial inputs used to calculate the Rural Access Index (RAI)
3. Explain why the choice of gridded population input can lead to different results for this "simple" indicator.
4. Recognize the advantages and the limitations of using currently available open global data sources to calculate RAI

Sustainable Development Goal (SDG) 9

Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

Target 9.1: ...development of a quality, reliable, and resilient transport network....

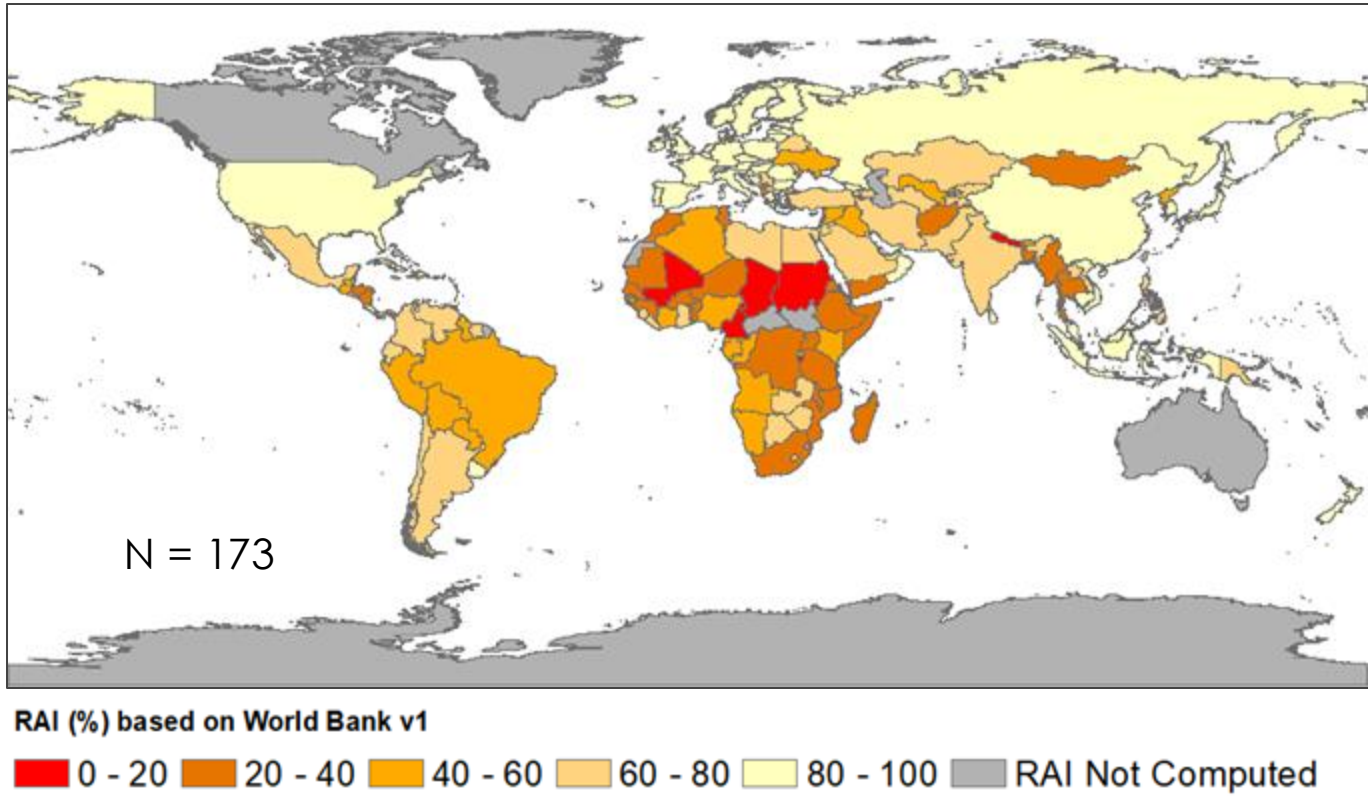
Indicator 9.1.1 - The Rural Access Index (RAI)

Proportion of the rural population who live within 2 km of an all-season road

Measuring Rural Access to Roads

The Rural Access Index (RAI), World Bank Version 1

- *Rural Access Index: A Key Development Indicator*
  World Bank Transport Unit technical paper by Roberts et al. (2006)
- Approaches to measuring RAI:
  - *Preferred:* Household surveys with questions about access to transport
  - *Alternative:* GIS methods and model estimations where data inputs were available
- RAI Computed for 173 countries at the ***national level only***.



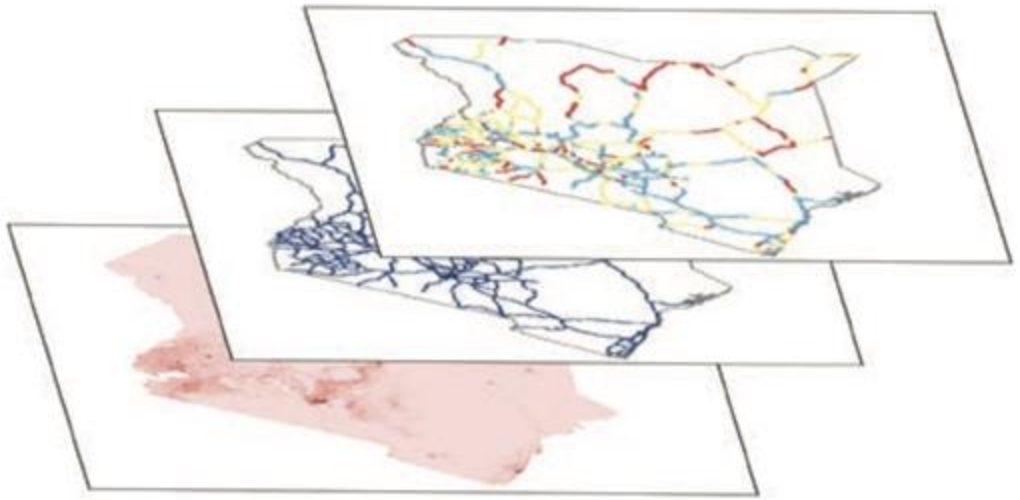
Measuring Rural Access to Roads

The Rural Access Index (RAI), World Bank Version 2

Measuring Rural Access: Using New Technologies, 2016 Transport & ICT Report

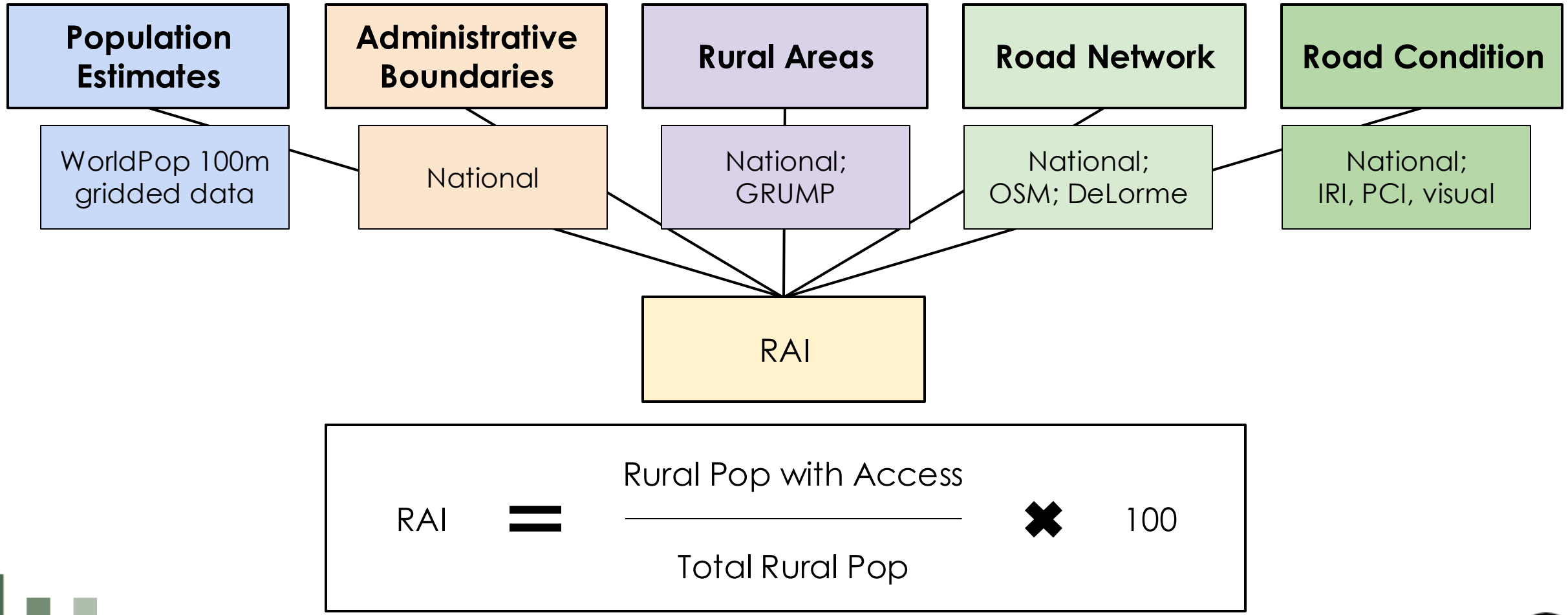
Figure AI.1: Basic Methodological Framework

Population distribution	• Where do people live?
Road network	• Where are the roads?
Road condition	• Are they in good condition?



Measuring Rural Access to Roads

World Bank geospatial RAI data inputs and sources

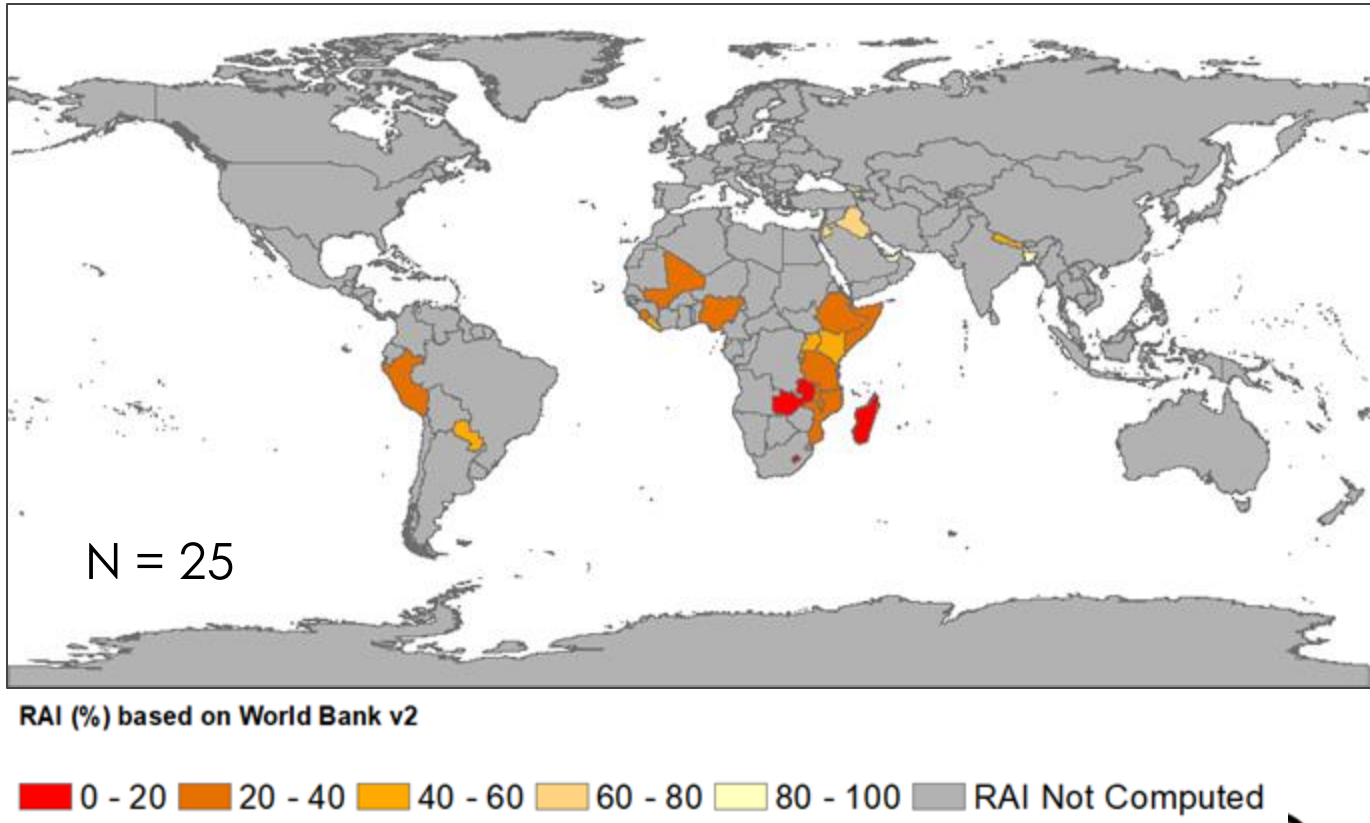


Measuring Rural Access to Roads

The Rural Access Index (RAI), World Bank Version 2

Advantages of the geospatial methodology:

- More cost-effective and sustainable; no need to wait for the next survey
- More consistent across countries
- Allows for subnational RAI estimation - aiding prioritization of rural road improvements and monitoring
- 25 countries completed thus far

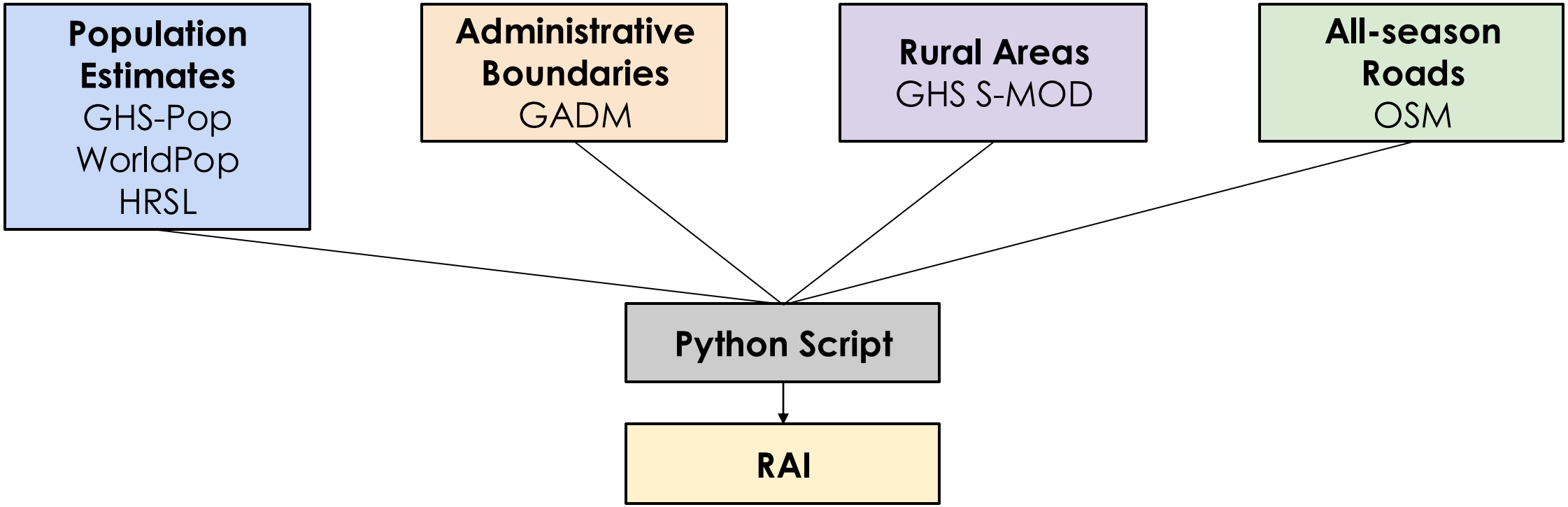


A Global Open Data Approach to the RAI

Advantages of using Open Global datasets to calculate RAI for every country:

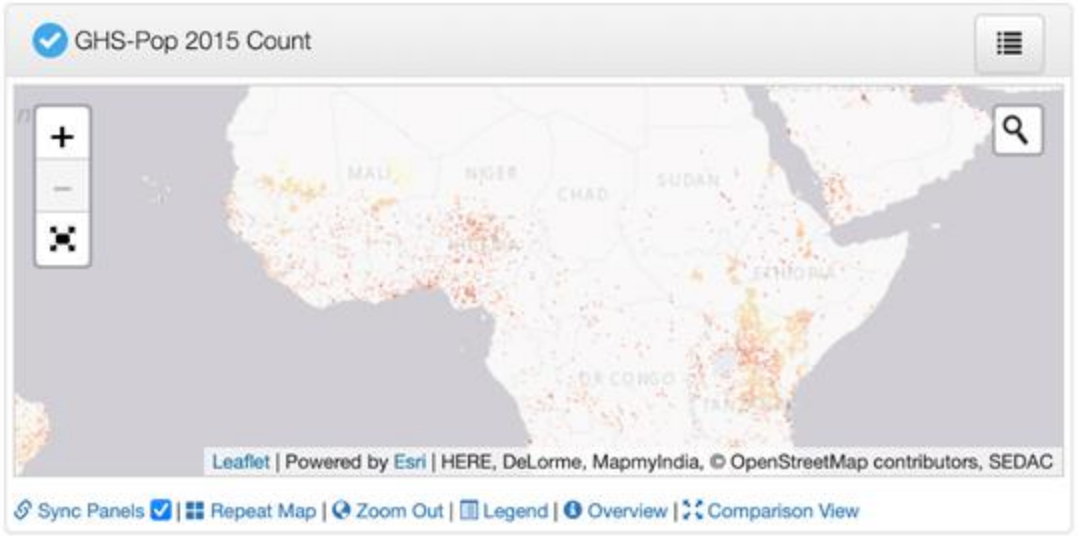
- **Common inputs** enable better cross-country comparison
  - Common gridded population estimates - several choices
  - Standardized national boundaries (GADM)
  - Common urban/rural definition (S-MOD) based on population density, counts, & satellite-derived built-up areas
  - Common road classification (OSM); continuously updated
- **Automated script** for faster processing and ease of repeatability
- **Temporal comparison** possible as datasets are updated

A Global Open Data Approach to the RAI

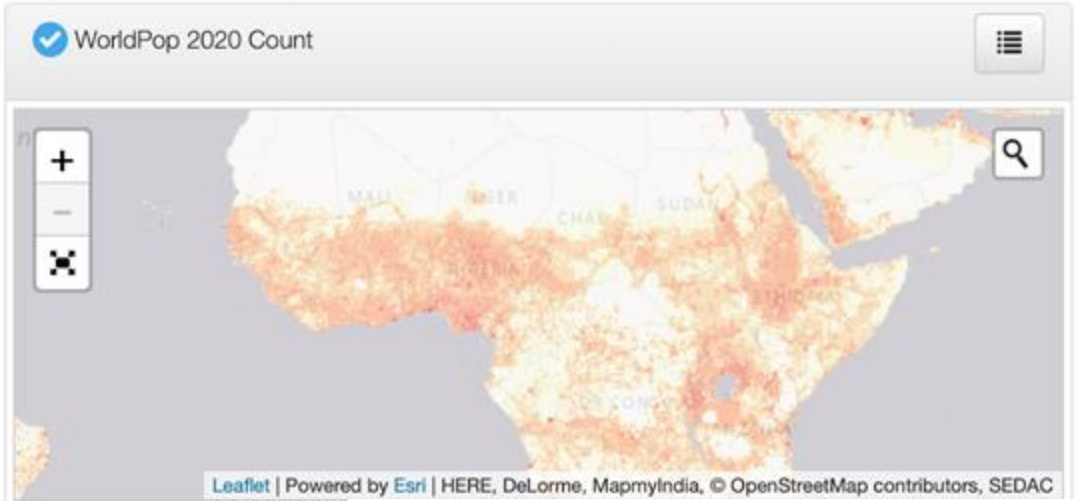


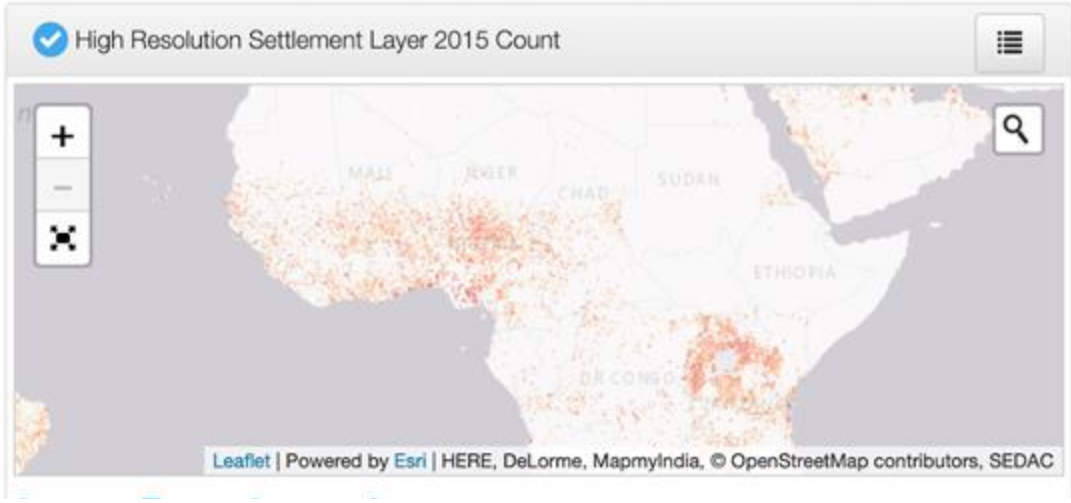
$$RAI = \frac{\text{Rural Pop with Access}}{\text{Total Rural Pop}} \times 100$$

Population Input: Three Gridded Population Datasets



- Global Human Settlement Population 2015 (GHS-POP)
- WorldPop 2020 (WP)
- High Resolution Settlement Layer 2015 (HRSL)





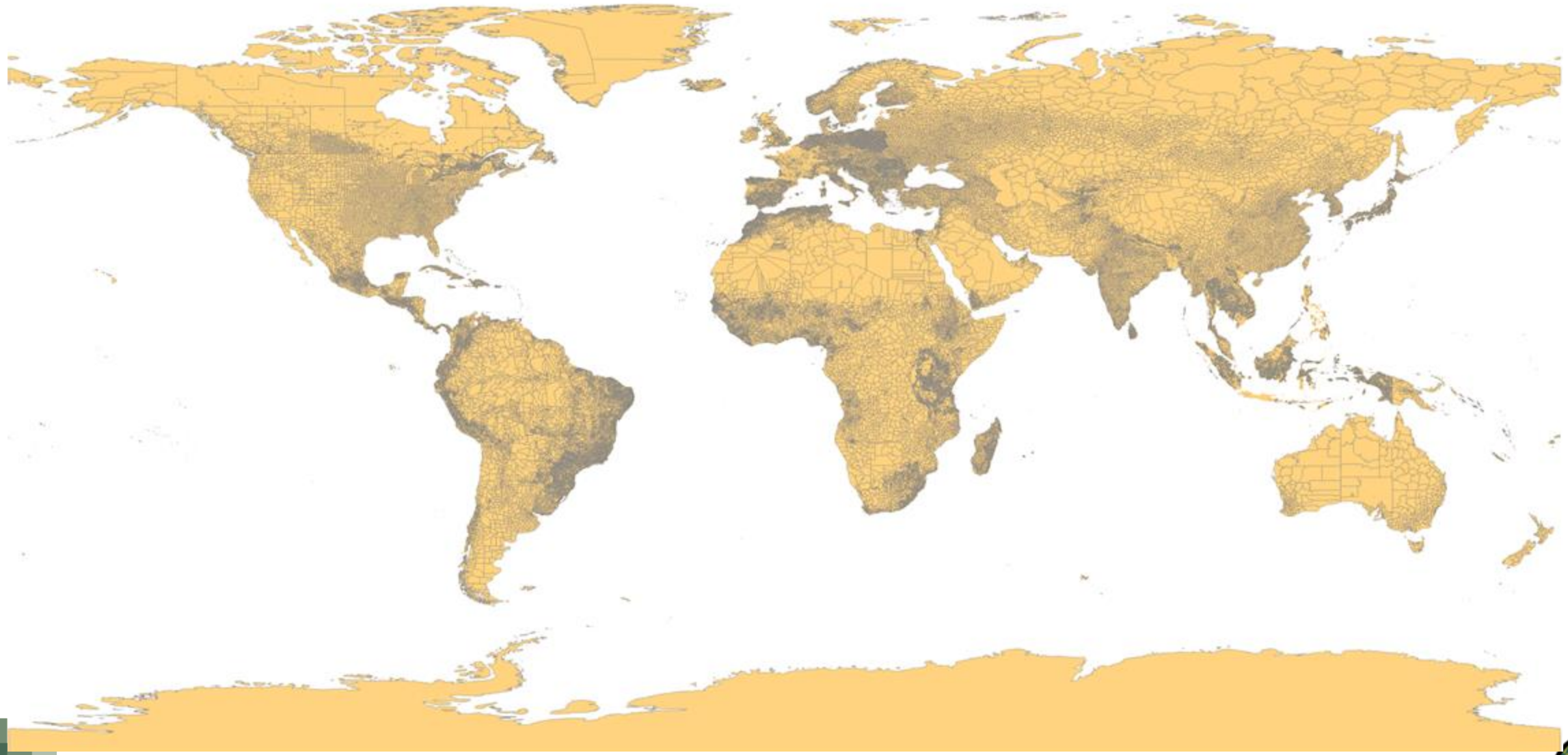
Popgrid Viewer: https://sedac.ciesin.columbia.edu/mapping/popgrid/

Population Inputs Compared

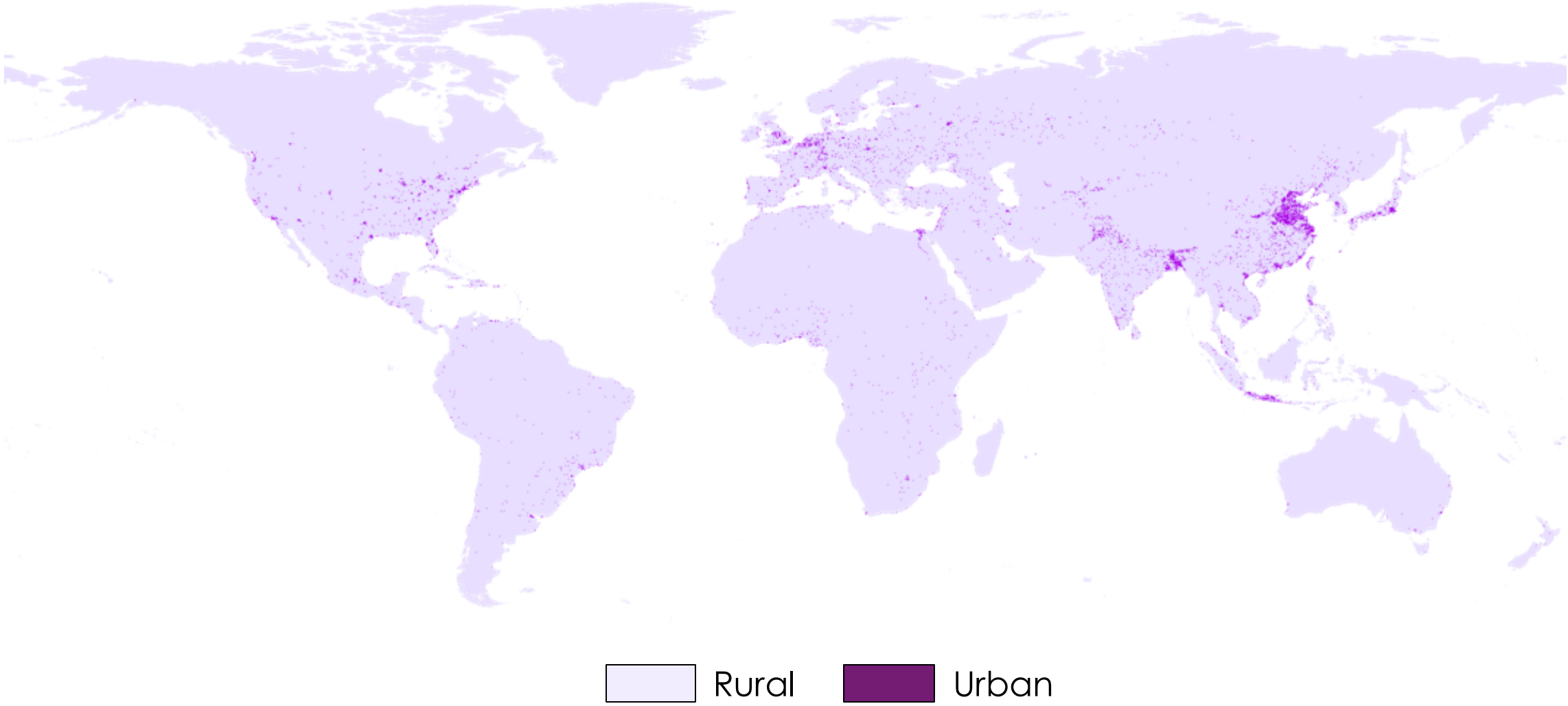
Dataset	Source	Concept/Method	Resolution
Global Human Settlement Population 2015 (GHS-POP)	JRC & CIESIN	• Lightly modeled • Binary dasymetric: Proportional allocation of census population to Landsat-derived built up areas	1 km (30 arc-seconds)
WorldPop 2020 (WP)	WorldPop	• Highly modeled • Random Forest model and dasymetric redistribution: Census population allocated to grid cells based on statistical weighting of co-variate layers, e.g., urban extents, land cover, roads….	100 m (3-arc seconds)
High Resolution Settlement Layer 2015 (HRSL)	Facebook & CIESIN	• Lightly modeled • Binary dasymetric: Proportional allocation of census population to satellite-derived "settlement extents" defined by the presence of buildings	30 m (1 arc-second)

Source: https://www.popgrid.org/explore-data

Admin Input: Database of Global Administrative Areas (GADM)



Rural Areas Input: GHS Settlement Model (GHS-SMOD)



Roads Input: OpenStreetMap (OSM)

Global OSM roads data was downloaded as a geopackage from: https://download.osmdata.xyz

Global openstreetmap data extracts | osmdata.xyz

Introduction: This project provides global data extracts based on OpenStreetMap data as GeoPackages. Each extract represents its related primary feature regarding the OpenStreetMap project.

Information about this project and data processing: osmdata.xyz on GitHub

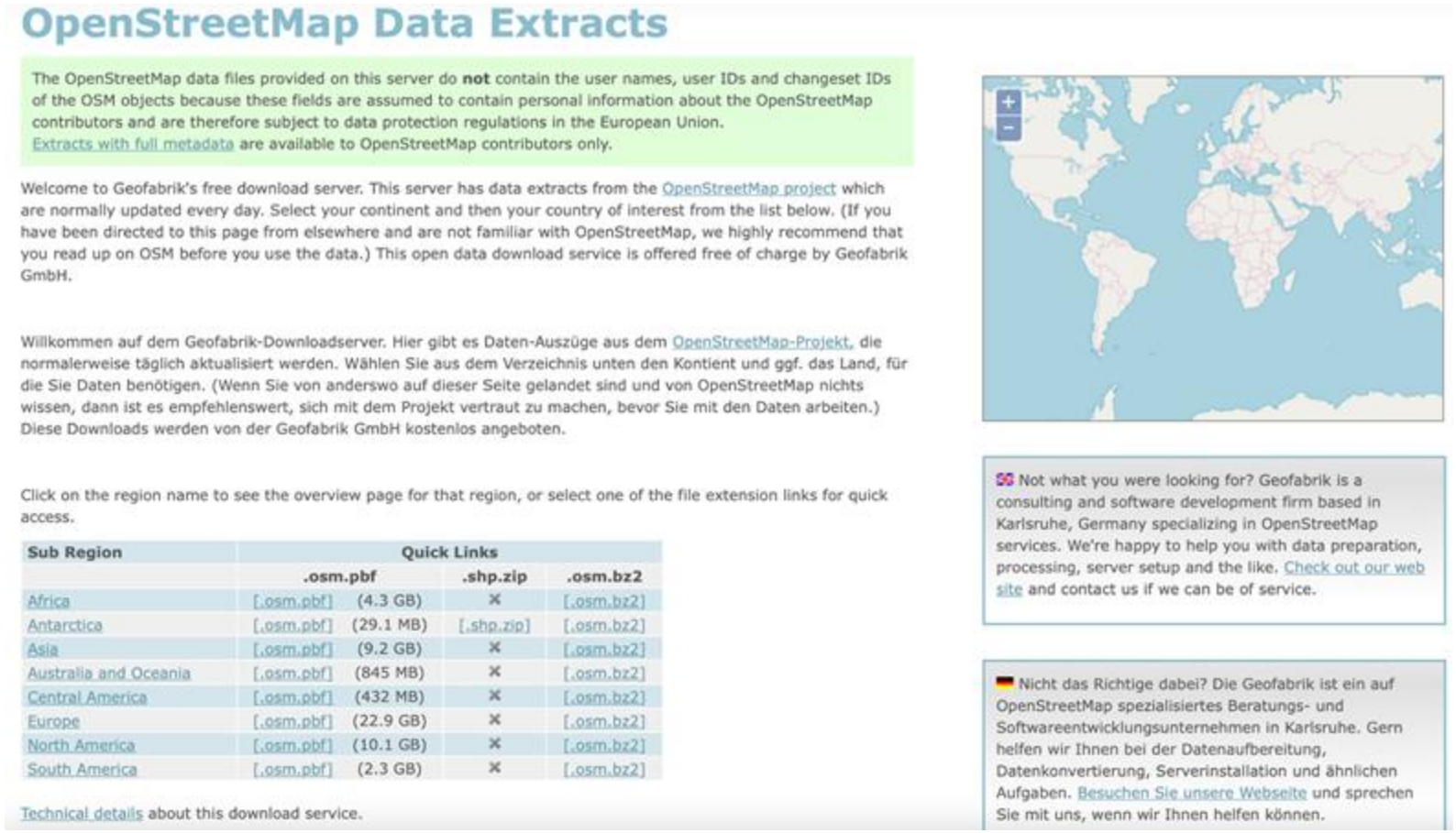
Updates are available every month. Building is updated every odd month.

Downloads

Note: The GeoPackages are compressed into ZIP-Archives. Projection of the geodata: WGS 84 | EPSG 4326

Name	File	ZIP size MB approx.	GeoPackage size MB approx.	Last update dd.mm.yyyy
Address	address_EPSG4326.zip	13.682	49.009	04.01.2021
Aerialway	aerialway_EPSG4326.zip	7	32	04.01.2021
Aeroway	aeroway_EPSG4326.zip	82	253	04.01.2021
Amenity	amenity_EPSG4326.zip	2.665	8.547	04.01.2021

Roads Input: OpenStreetMap (OSM)



OpenStreetMap Data Extracts

The OpenStreetMap data files provided on this server do **not** contain the user names, user IDs and changeset IDs of the OSM objects because these fields are assumed to contain personal information about the OpenStreetMap contributors and are therefore subject to data protection regulations in the European Union.
Extracts with full metadata are available to OpenStreetMap contributors only.

Welcome to Geofabrik's free download server. This server has data extracts from the OpenStreetMap project which are normally updated every day. Select your continent and then your country of interest from the list below. (If you have been directed to this page from elsewhere and are not familiar with OpenStreetMap, we highly recommend that you read up on OSM before you use the data.) This open data download service is offered free of charge by Geofabrik GmbH.

Willkommen auf dem Geofabrik-Downloadserver. Hier gibt es Daten-Auszüge aus dem OpenStreetMap-Projekt, die normalerweise täglich aktualisiert werden. Wählen Sie aus dem Verzeichnis unten den Kontient und ggf. das Land, für die Sie Daten benötigen. (Wenn Sie von anderswo auf dieser Seite gelandet sind und von OpenStreetMap nichts wissen, dann ist es empfehlenswert, sich mit dem Projekt vertraut zu machen, bevor Sie mit den Daten arbeiten.) Diese Downloads werden von der Geofabrik GmbH kostenlos angeboten.

Click on the region name to see the overview page for that region, or select one of the file extension links for quick access.

Sub Region	Quick Links		
	.osm.pbf	.shp.zip	.osm.bz2
Africa	[.osm.pbf] (4.3 GB)	✕	[.osm.bz2]
Antarctica	[.osm.pbf] (29.1 MB)	[.shp.zip]	[.osm.bz2]
Asia	[.osm.pbf] (9.2 GB)	✕	[.osm.bz2]
Australia and Oceania	[.osm.pbf] (845 MB)	✕	[.osm.bz2]
Central America	[.osm.pbf] (432 MB)	✕	[.osm.bz2]
Europe	[.osm.pbf] (22.9 GB)	✕	[.osm.bz2]
North America	[.osm.pbf] (10.1 GB)	✕	[.osm.bz2]
South America	[.osm.pbf] (2.3 GB)	✕	[.osm.bz2]

Technical details about this download service.

Not what you were looking for? Geofabrik is a consulting and software development firm based in Karlsruhe, Germany specializing in OpenStreetMap services. We're happy to help you with data preparation, processing, server setup and the like. Check out our web site and contact us if we can be of service.

Nicht das Richtige dabei? Die Geofabrik ist ein auf OpenStreetMap spezialisiertes Beratungs- und Softwareentwicklungsunternehmen in Karlsruhe. Gern helfen wir Ihnen bei der Datenaufbereitung, Datenkonvertierung, Serverinstallation und ähnlichen Aufgaben. Besuchen Sie unsere Webseite und sprechen Sie mit uns, wenn wir Ihnen helfen können.

Alternatively, country level OSM roads data can be downloaded Geofabrik Download Server: https://download.geofabrik.de

Roads Input: OpenStreetMap (OSM)

Osmdata.xyz https://github.com/michaelmgis/osmdata.xyz	**Geofabrik** https://download.geofabrik.de/
- Global extract	- Country extract
- Primary feature (e.g., highways) and all attributes	- Selection of features (e.g., land use, roads, waterways) and attributes
- Geopackage	- Shapefile
- Universal timestamp for the entire extract	- Different timestamps for each country

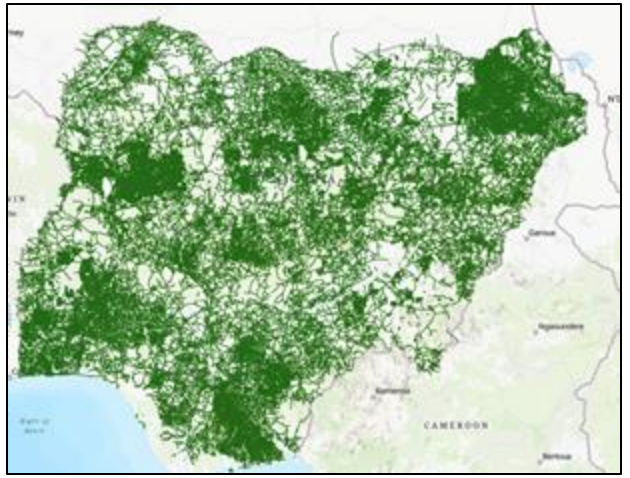
Defining OSM "All-season Roads"

Two definitions based on OSM "fclass" attribute

OSM fclass	World Bank	CIESIN
Primary & primary link	✓	✓
Secondary & secondary link	✓	✓
Tertiary & tertiary link	✓	✓
Trunk	✓	✓
Motorway	✓	✓
Unclassified	-	✓
Track Grade 1	-	✓
Unknown	-	✓
Road	-	✓

World Bank Definition

CIESIN Definition



Global Open Data RAI Script

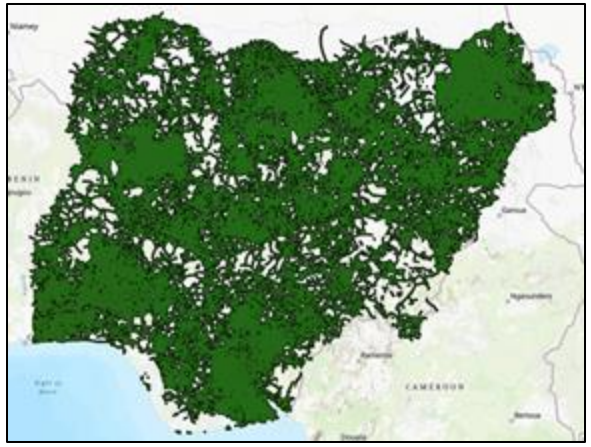
Dissolve
GADM to Admin 0 and Admin 2

Convert
S-MOD to Polygon
Extract
Rural Areas

Filter & Buffer
OSM Roads
Dissolve
Buffers

Admin 0

Admin 2



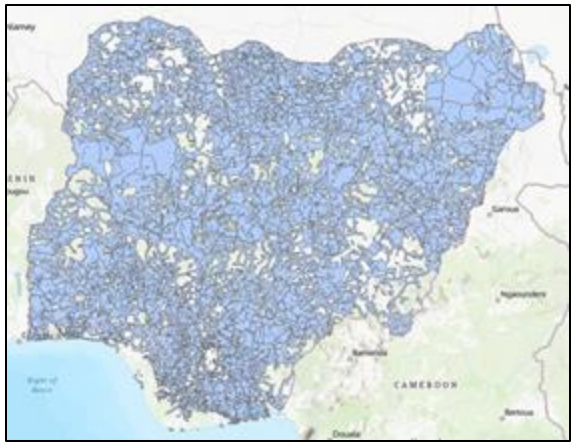
Global Open Data RAI Script (continued)

Intersect
Admin 2, Rural Areas, & Buffer

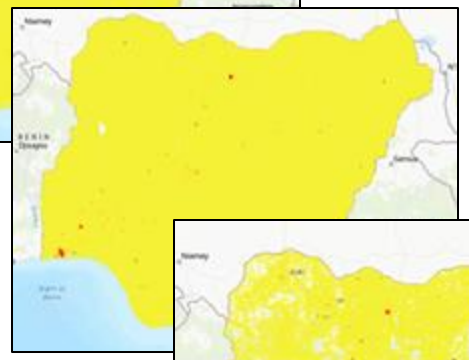
Clip
Pop Grids

Zonal Statistics
on Pop Grids with Admin 2 Rural Buffers

Admin 2 Rural Road Buffers



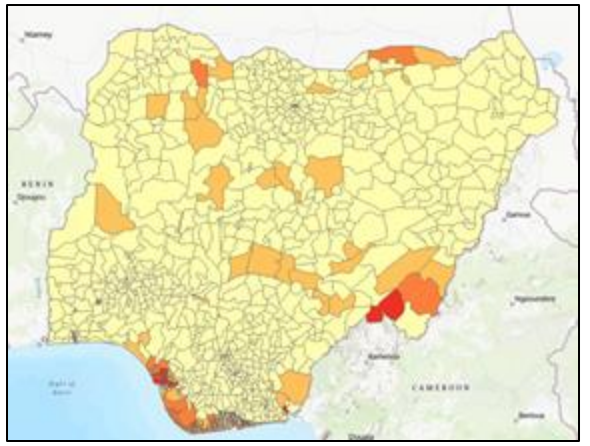
GHS-Pop



WorldPop

HRSL

$$RAI = \frac{\text{Rural Population with Access to Roads}}{\text{Total Rural Pop}} \times 100$$



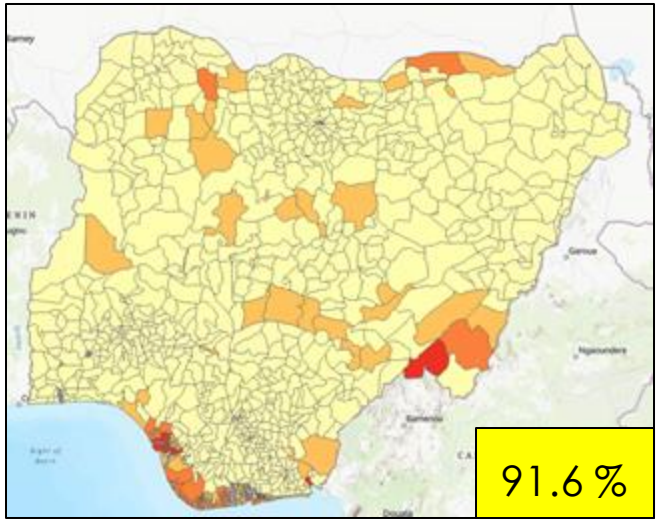
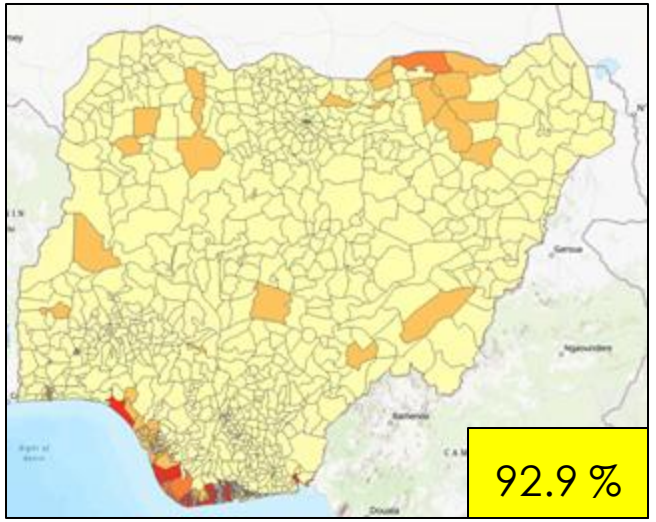
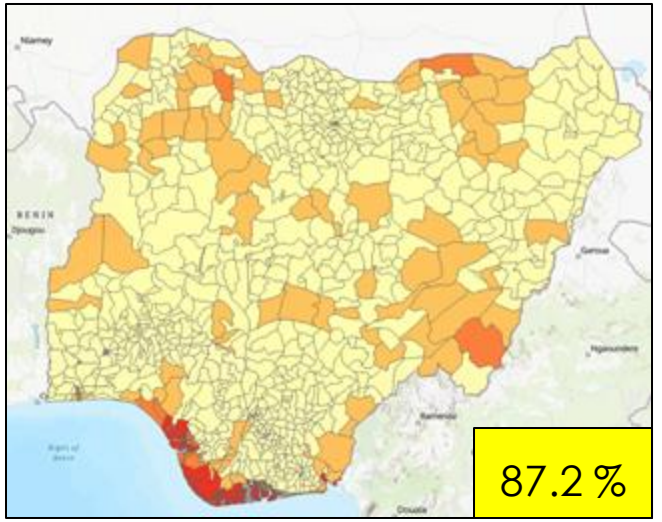
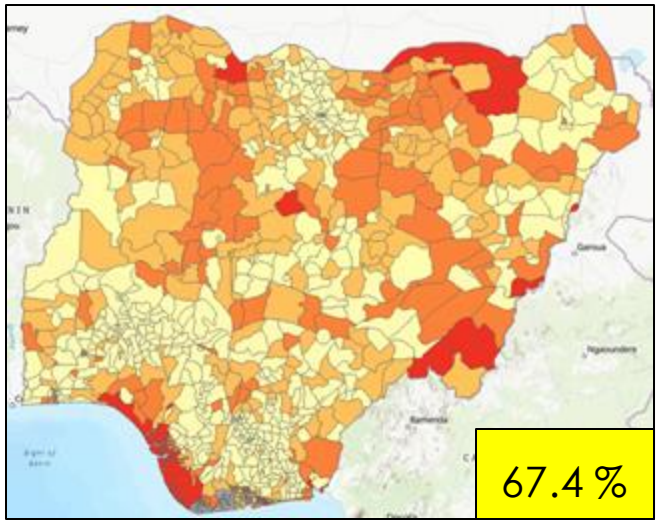
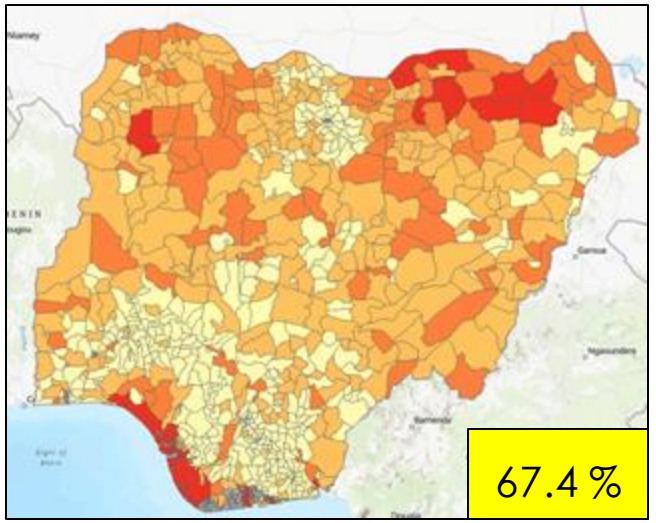
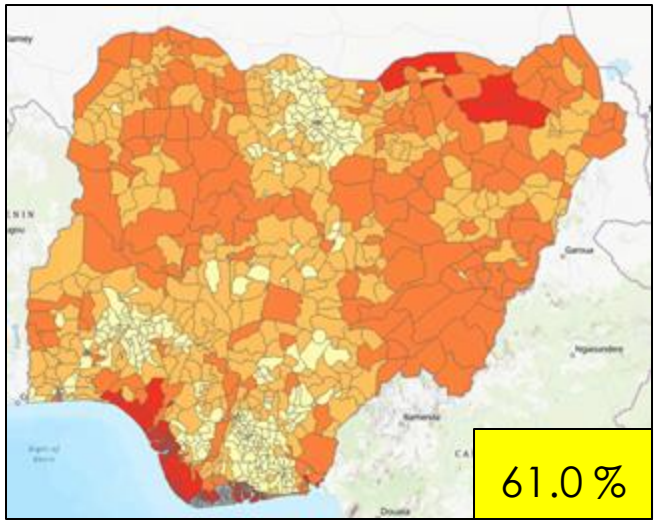
Pilot Results with Global Open Data

Country	Population Data Set	Total Rural Population	Rural Population within 2km of Roads	% of Rural Population within 2 km of Roads
Nigeria 1	GRID3	86,073,240	80,056,026	93.0
	HRSL	91,823,234	84,610,846	92.1
	GHS Pop	49,553,503	45,167,977	91.1
Nigeria 2	GRID3	86,073,240	55,136,377	64.1
	HRSL	91,823,234	59,071,979	64.3
	GHS Pop	49,553,502	33,317,594	67.2
Colombia	HRSL	21,304,160	18,396,019	86.3
	GHS Pop	7,589,940	6,894,459	90.8
Spain	HRSL	14,892,604	14,676,806	98.6
	GHS Pop	11,072,657	10,960,981	99.0

RAI results for Nigeria (1, with "unclassified" roads; 2, without "unclassified" roads), Colombia, and Spain using different gridded population inputs.

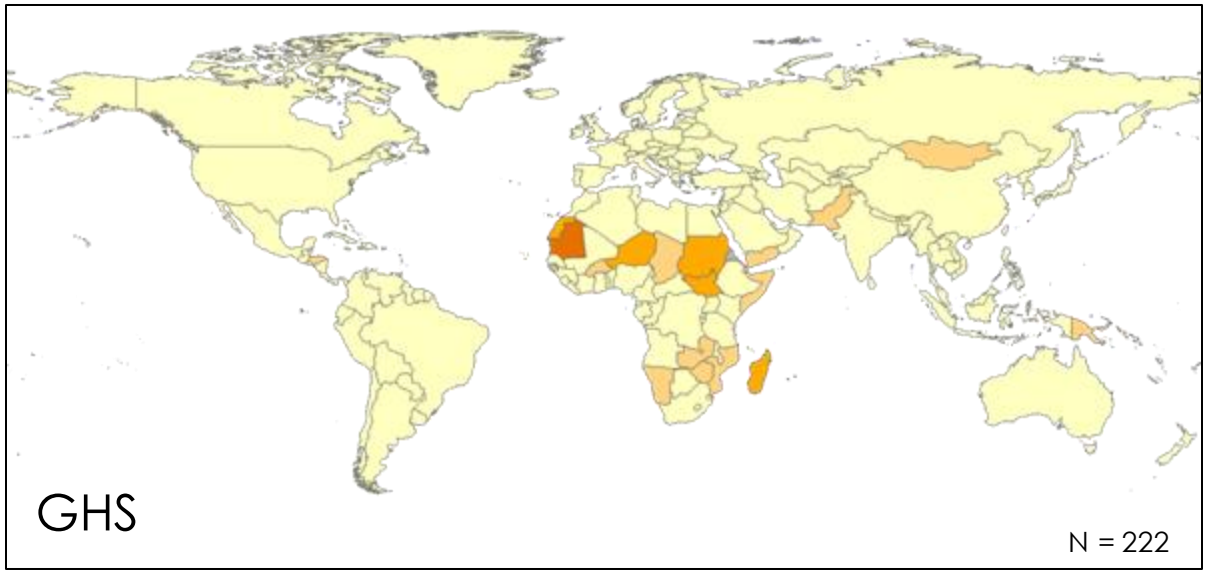
Source: Rural Access to Roads StoryMap on SDGs Today
https://arcg.is/04PaHv

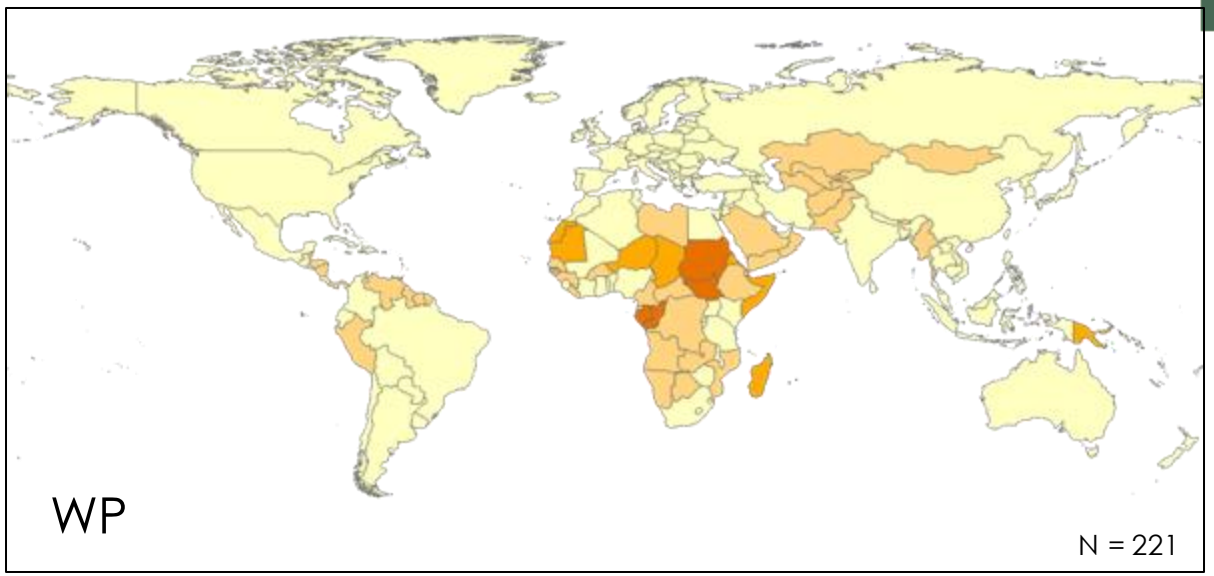
Global Open Data RAI Results: Nigeria

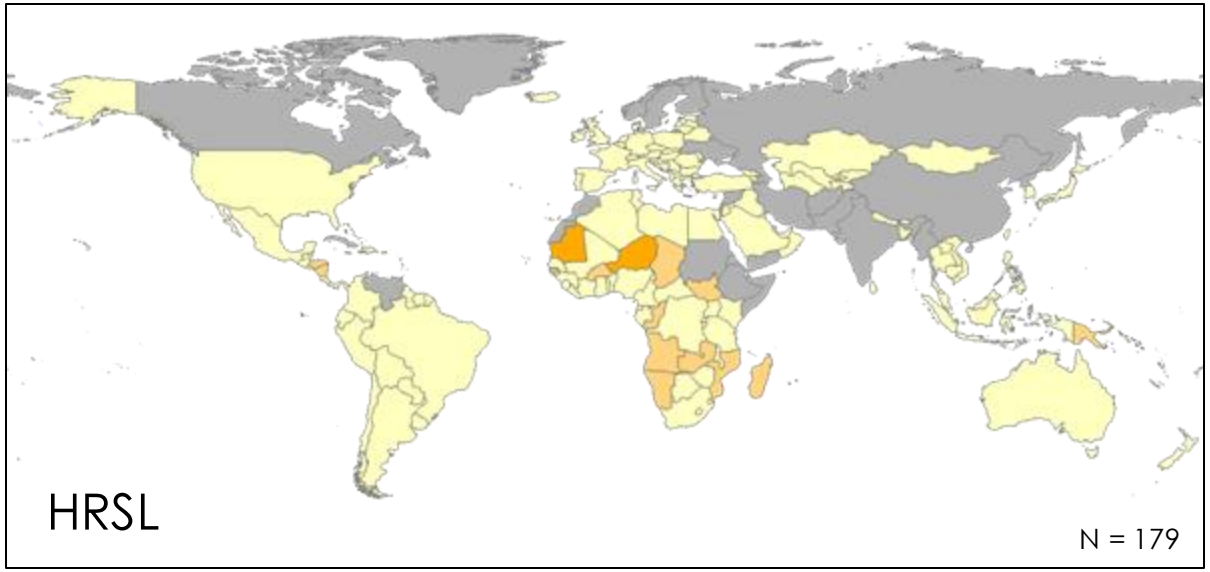
	GHS	HRSL	WP
CIESIN Roads Definition	 91.6 %	 92.9 %	 87.2 %
World Bank Roads Definition	 67.4 %	 67.4 %	 61.0 %

75-100 % 50-75 % 25-50 % 0-25 % N/A

National RAI Results: CIESIN Roads Definition





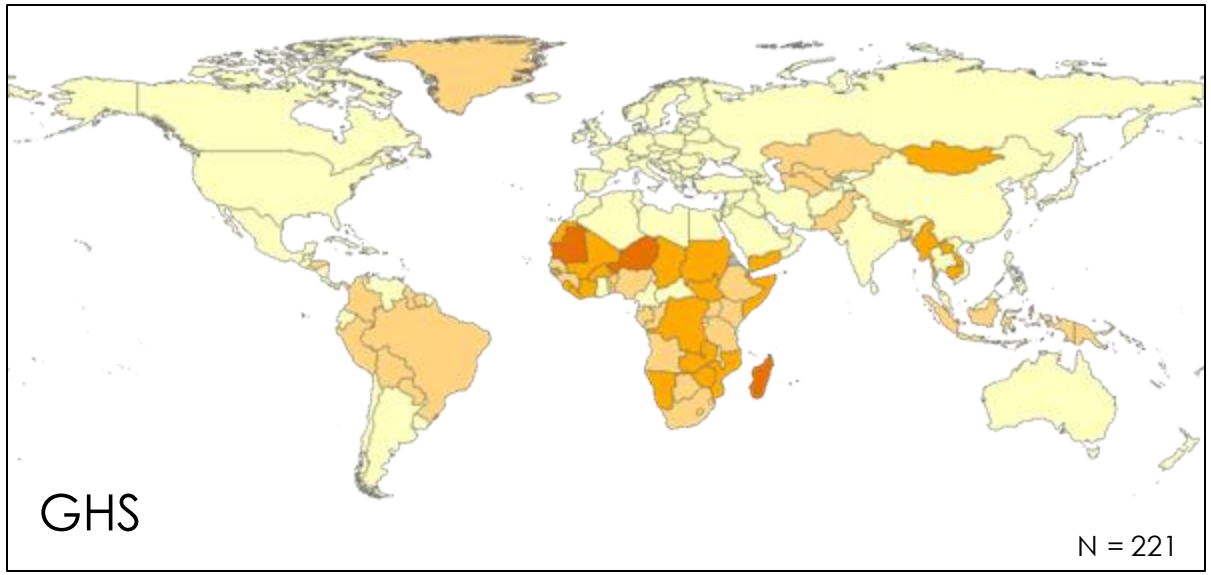


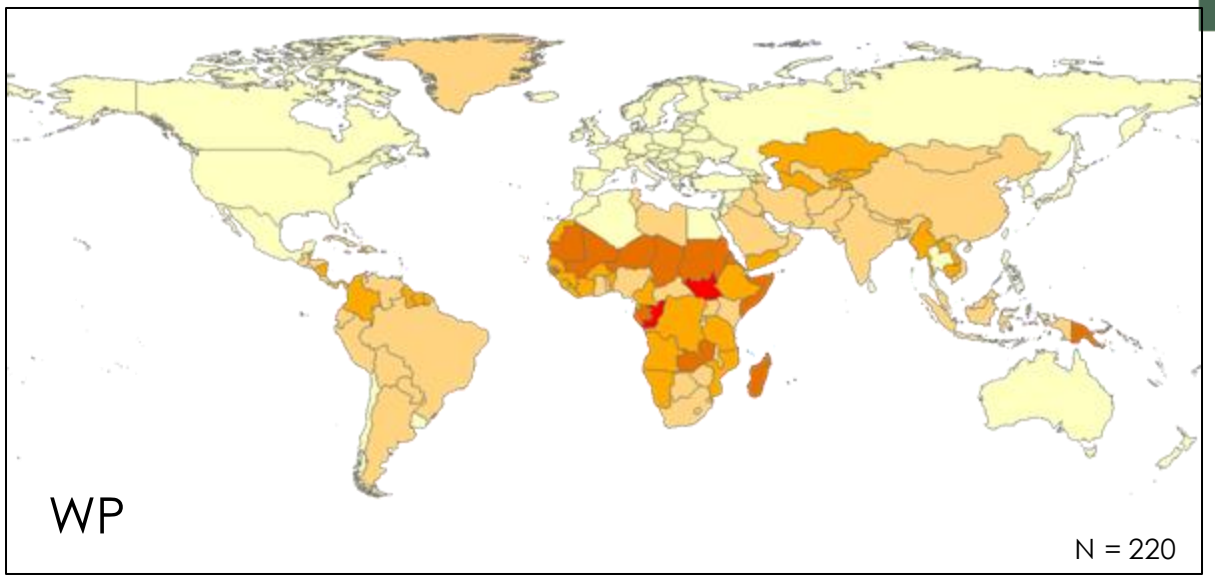
* Akrotiri and Dhekelia, Kosovo, Aland, and Northern Cyprus are excluded from this map because they do not have official UN population values for verifying their results.

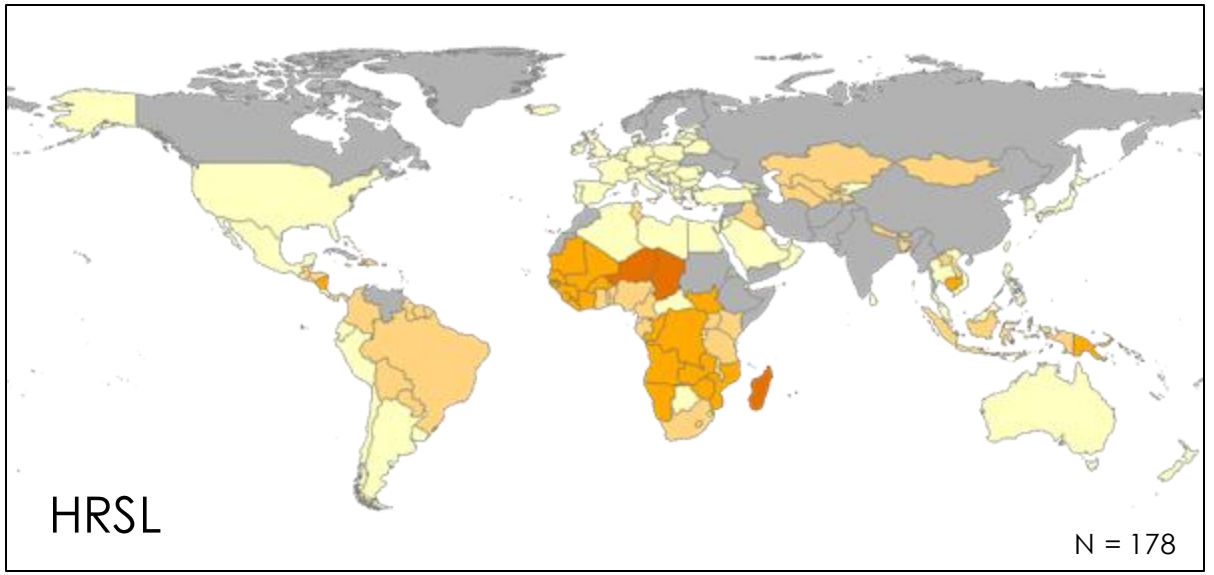
** Countries with a population percent error greater than 50 % when compared to official UN population values are excluded from this map.

0 - 20 | 20 - 40 | 40 - 60 | 60 - 80 | 80 - 100 | RAI Not Computed

National RAI Results: World Bank Roads Definition





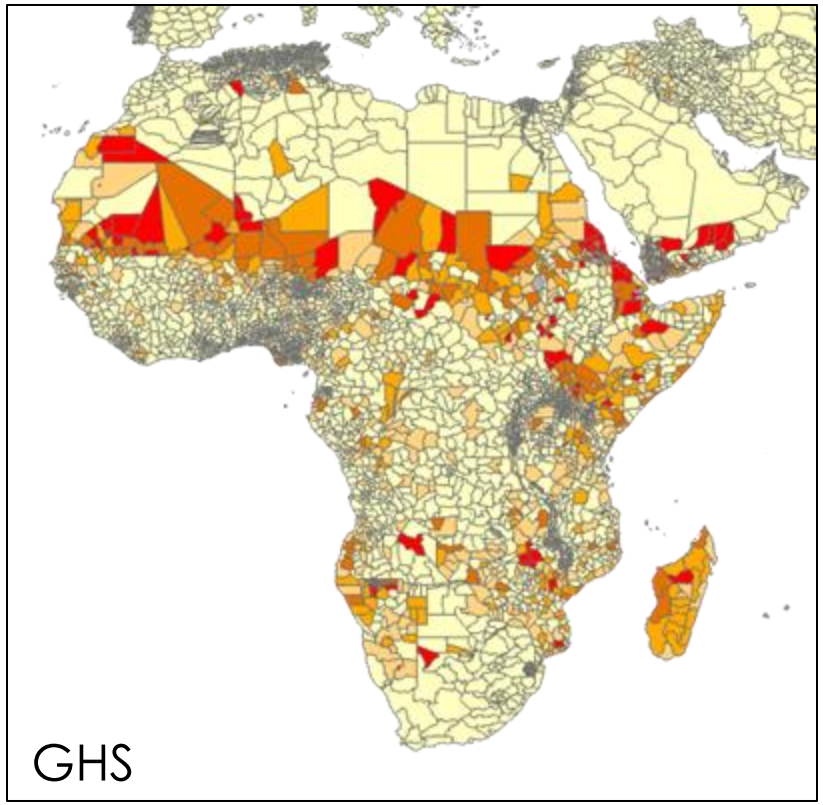


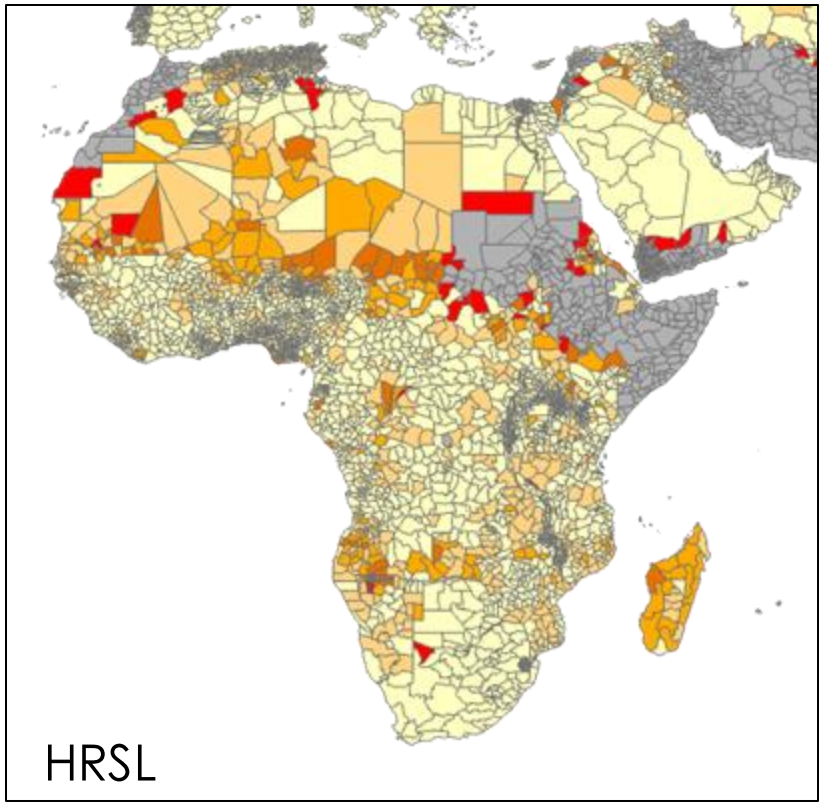
* Akrotiri and Dhekelia, Kosovo, Aland, and Northern Cyprus are excluded from this map because they do not have official UN population values for verifying their results.

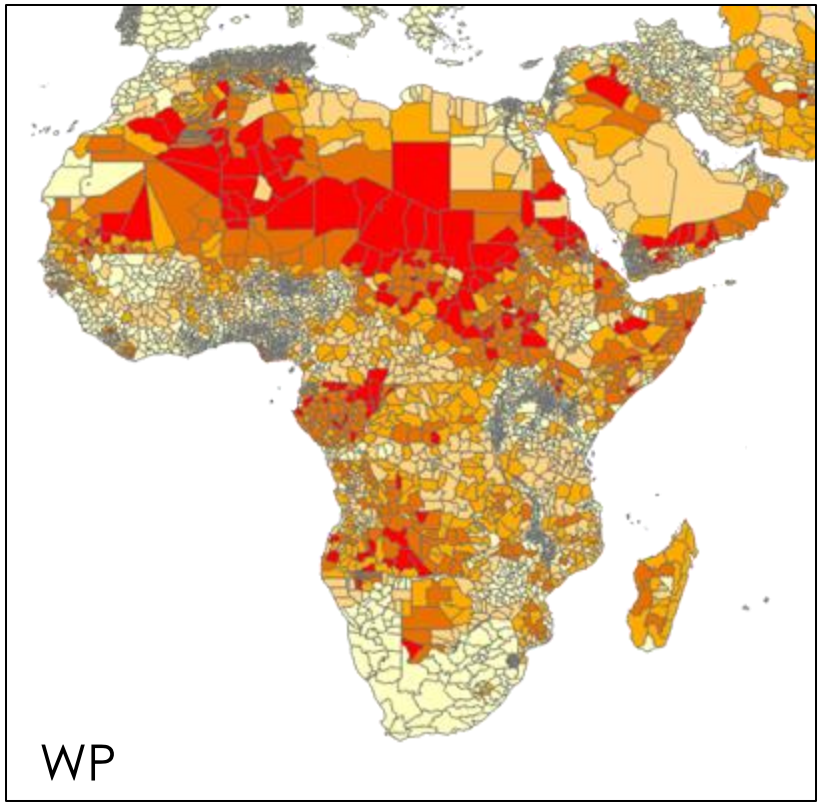
** Countries with a population percent error greater than 50 % when compared to official UN population values are excluded from this map.

0 - 20 | 20 - 40 | 40 - 60 | 60 - 80 | 80 - 100 | RAI Not Computed

Africa Subnational (L2) RAI Results: CIESIN Roads Definition



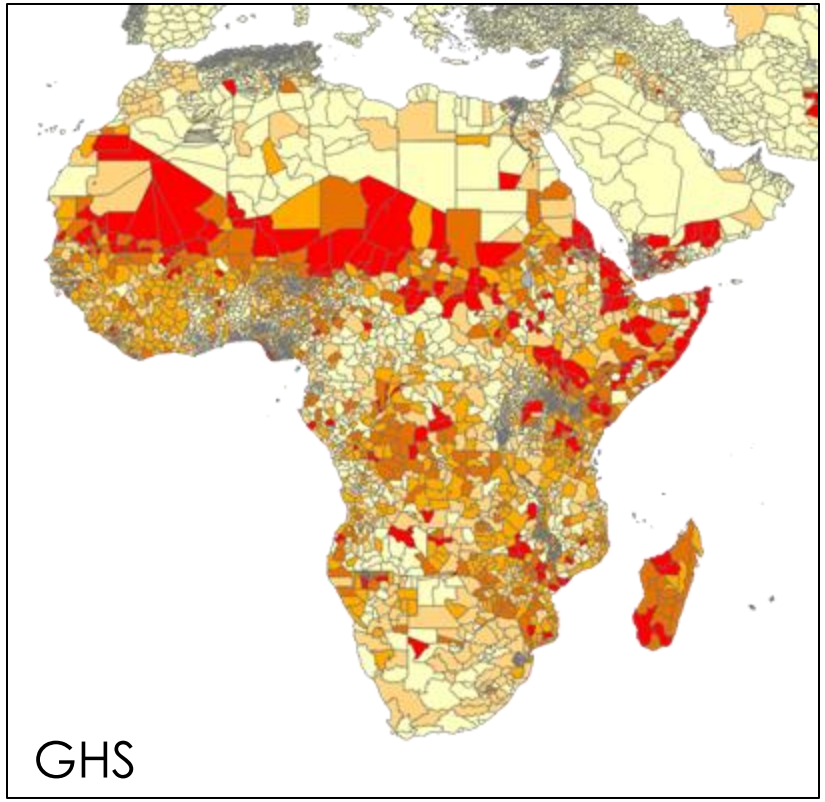


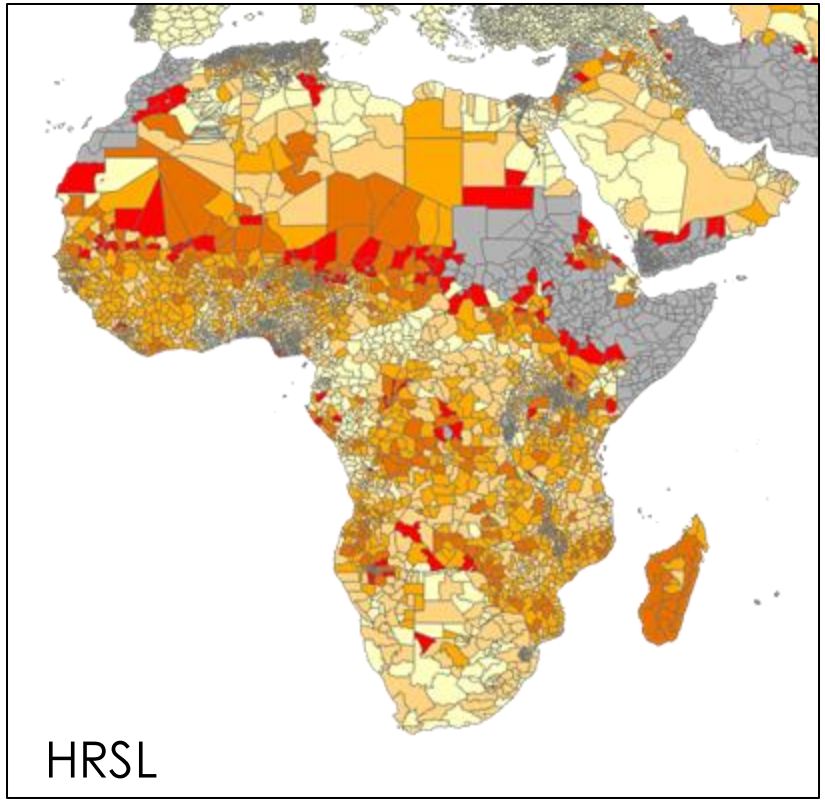


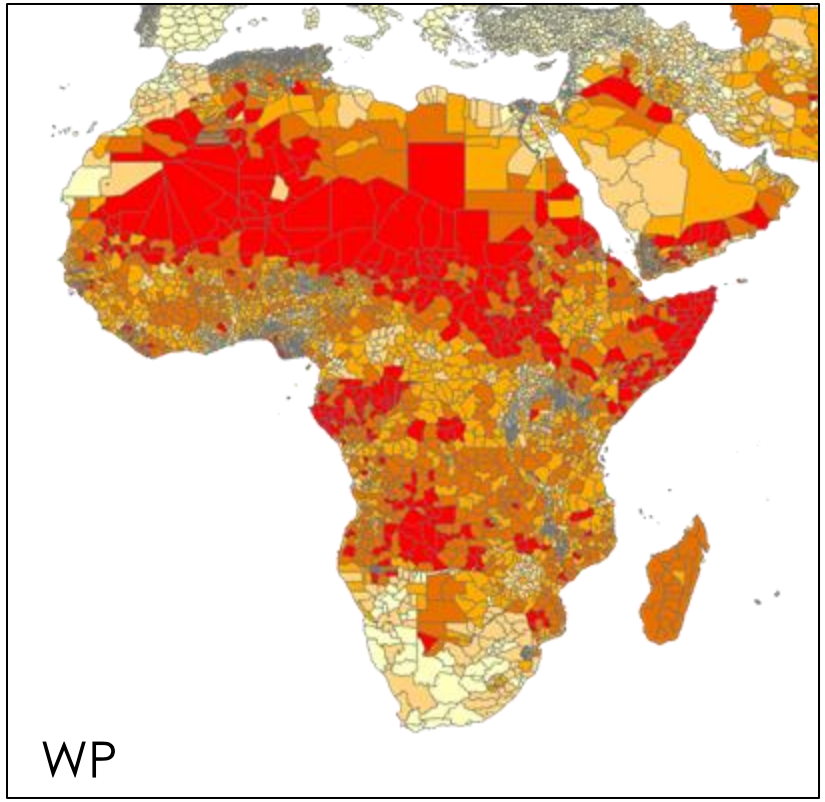
N = 8,436

0 - 20 | 20 - 40 | 40 - 60 | 60 - 80 | 80 - 100 | RAI Not Computed

Africa Subnational (L2) RAI Results: World Bank Roads Definition







N = 9,364

0 - 20 | 20 - 40 | 40 - 60 | 60 - 80 | 80 - 100 | RAI Not Computed

Preliminary Global Average RAI Results

World Bank Roads Definition

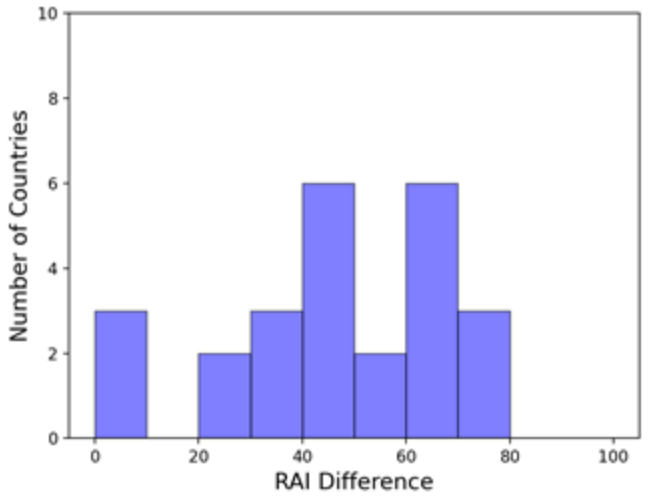
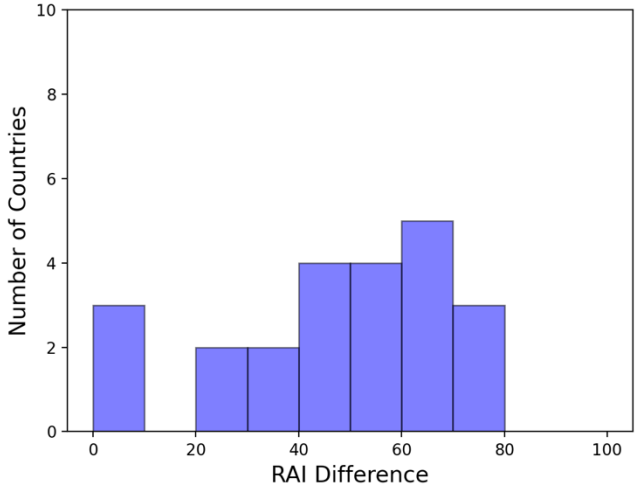
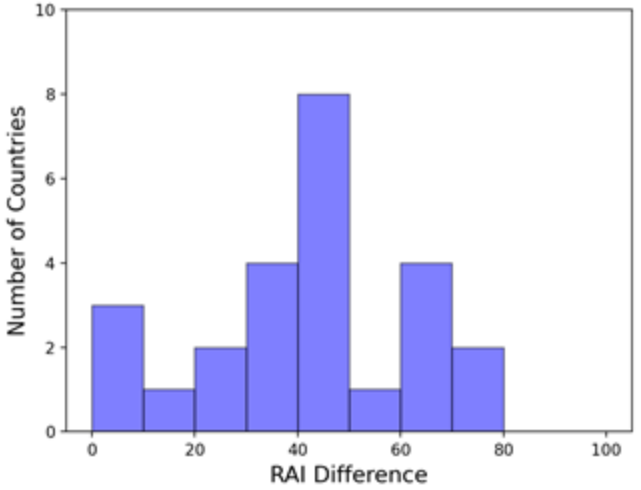
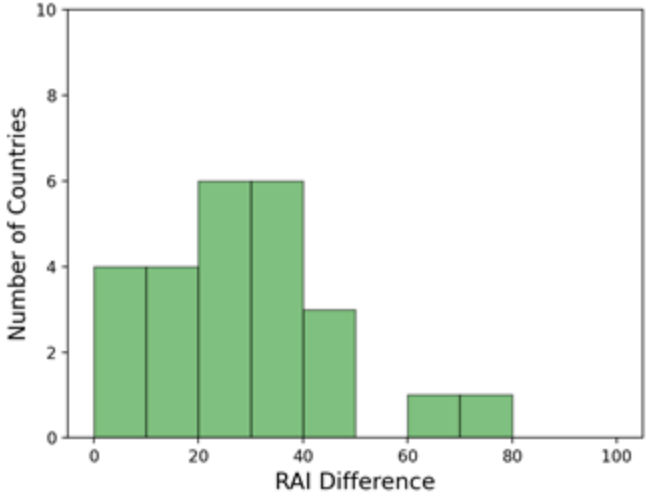
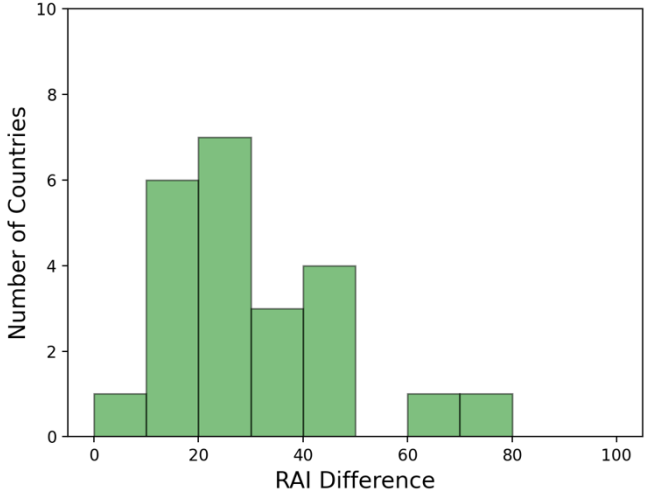
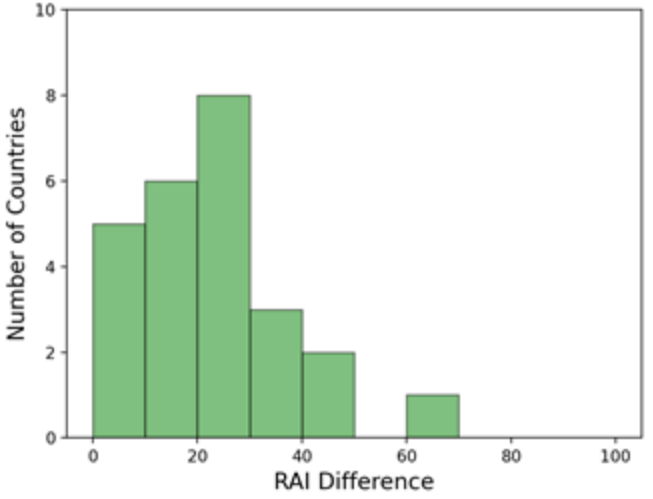
	GHS	HRSL	WP
AVERAGE	83.4	82.9	76.4
STDEV	18.2	16.7	21.1
N	221	178	220

CIESIN Roads Definition

	GHS	HRSL	WP
AVERAGE	92.4	93.8	86.7
STDEV	12.3	9.1	15.5
N	222	179	221

- CIESIN's more inclusive selection of "all-season" roads results in global average RAIs that are consistently ~10 percentage points greater than the averages computed with the World Bank definition.
- For both definitions, GHS & HRSL averages are generally consistent with each other and ~8 points higher than the WP results.
- This is consistent with WP often predicting lower RAIs for a given unit, due likely to the the manner in which the model allocates population to large rural areas.

RAI Difference: Global Open Data vs World Bank Country Level

	GHS	HRSL	WP
CIESIN Roads Definition			
World Bank Roads Definition			

Limitations of the Global Open Data Approach to the RAI

Gridded population estimates	• Several data sets to choose from, each with their own bias • varying frequency of updates
GADM national boundaries	• Resolution varies by country • Handling of disputed territories • Infrequent/unpredictable updates
S-MOD urban/rural areas	• Potential misalignment with national urban/rural delineation
OSM roads	• Variable coverage, especially in rural areas • Limited road condition information • "fclass" attribute as a proxy requires further refinement • Data not associated with government responsibility

Accuracy ultimately depends on the quality of OSM roads data for a given country.

Let's Review...

- SDG indicator 9.1.1, the **Rural Access Index** (RAI), measures **rural access to all-season roads.**
- RAI can be effectively calculated by combining geospatial data for **administrative units**, **rural areas, roads**, and **population.**
- While their are **advantages** to using global datasets, such as standard inputs, automation, and temporal comparisons, there are also **limitations**.
- The choice of **POPGRID** dataset and **OSM road selections** significantly impact RAI results calculated using this method.
- **This is a simple and effective method for monitoring RAI globally.**

References:

Roberts, Peter; KC, Shyam; Rastogi, Cordula. 2006. *Rural Access Index : A Key Development Indicator*. Transport paper series; no. TP-10. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/17414 License: CC BY 3.0 IGO.

Transport & ICT. 2016. *Measuring Rural Access: Using New Technologies.* Washington DC: World Bank, License: Creative Commons Attribution CC BY 3.0 http://documents.worldbank.org/curated/en/367391472117815229/Measuring-rural-access-using-new-technologies

World - Measuring Rural Access : Update 2017/18 (English). Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/543621569435525309/World-Measuring-Rural-Access-Update-2017-18

Schiavina, Marcello; Freire, Sergio; MacManus, Kytt (2019): GHS population grid multitemporal (1975, 1990, 2000, 2015) R2019A. European Commission, Joint Research Centre (JRC) DOI: 10.2905/42E8BE89-54FF-464E-BE7B-BF9E64DA5218 PID: http://data.europa.eu/89h/0c6b9751-a71f-4062-830b-43c9f432370f

Pesaresi, Martino; Florczyk, Aneta; Schiavina, Marcello; Melchiorri, Michele; Maffenini, Luca (2019): GHS settlement grid, updated and refined REGIO model 2014 in application to GHS-BUILT R2018A and GHS-POP R2019A, multitemporal (1975-1990-2000-2015), R2019A. European Commission, Joint Research Centre (JRC) DOI: 10.2905/42E8BE89-54FF-464E-BE7B-BF9E64DA5218 PID: http://data.europa.eu/89h/42e8be89-54ff-464e-be7b-bf9e64da5218

Worldpop. "Open Spatial Demographic Data and Research." WorldPop. Accessed February 03, 2021. https://www.worldpop.org/.

"Methodology: High Resolution Population Density Maps Demographic Estimates." Facebook Data for Good. February 02, 2020. Accessed February 04, 2021. https://dataforgood.fb.com/docs/methodology-high-resolution-population-density-maps-demographic-estimates/.

"SDG Indicators - SDG Indicators." United Nations. Accessed February 04, 2021. https://unstats.un.org/sdgs/metadata/?Text=&Goal=9&Target=9.1.

"GADM Maps and Data." GADM. Accessed February 04, 2021. https://gadm.org/.

"Global Openstreetmap Data Extracts." Osmdata.xyz. Accessed February 04, 2021. https://download.osmdata.xyz/.

"Our Download Server." GEOFABRIK // Downloads. Accessed February 15, 2021. https://www.geofabrik.de/data/download.html.

"High Resolution Settlement Layer." Center for International Earth Science Information Network. Accessed March 08, 2021. https://ciesin.columbia.edu/data/hrsl/.

Worldpop. "WorldPop Methods." WorldPop. Accessed March 08, 2021. https://www.worldpop.org/methods.

"Global Population Grids: Summary Characteristics." Home. Accessed March 08, 2021. https://www.popgrid.org/data-docs-table1.

2021 ARSET-Applied Sciences Disasters Program

Population Grid Use Cases: Modeling Building Exposure data for DRR

Charles K. Huyck, Co-Founder ImageCat

March 30th and April 6th , 2021

Funding and Background

- Research funded by UK Space Agency International Partnership Programme: Project METEOR
- And through the NASA Disasters Program: Open Critical Infrastructure Exposure for Disaster Forecasting, Mitigation, and Response
- And Human Planet funding from NASA

https://meteor-project.org

METEOR

What you should learn in this lesson…

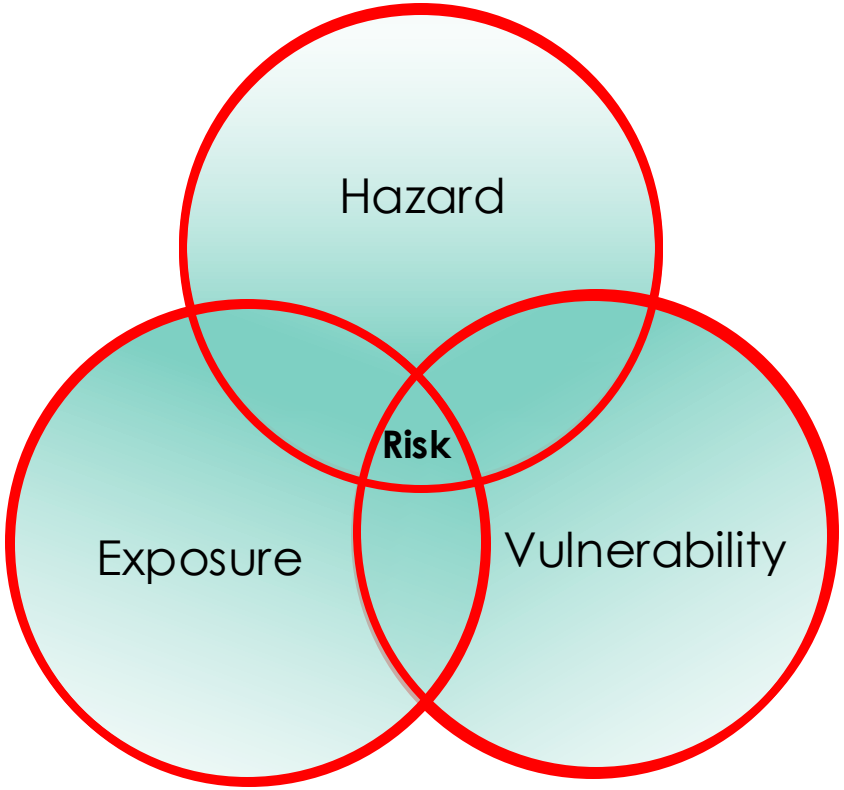
- What is exposure data and how is it used in the process of estimating losses from natural disasters?
- The basic process of developing exposure data
- The value of EO data
- Understanding uncertainty and the appropriate use of results

Loss Estimation and CAT (Catastrophe) Modeling for DRR

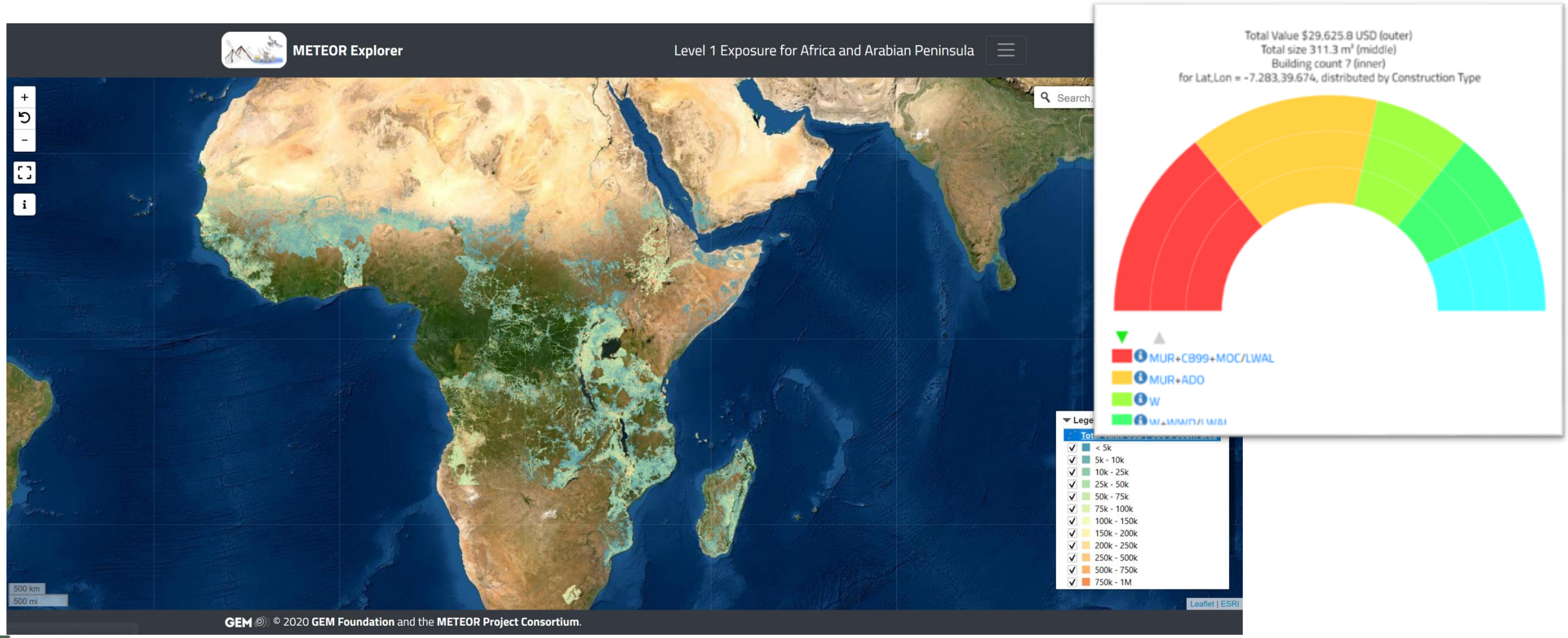
- **Before an Event -** What might happen if…?
- **During an Event -** Where is this going? What should we do?
- **After an Event -** What just happened? Should we ask for international help? Where is the most damage? Where are people without food and shelter?
- **On Average -** Where should we build stronger, higher, or farther away? Where should we retrofit, acquire property, or replace facilities? What should be insured? (Insurers- how much should that cost?)

What is Building Exposure for DRR?

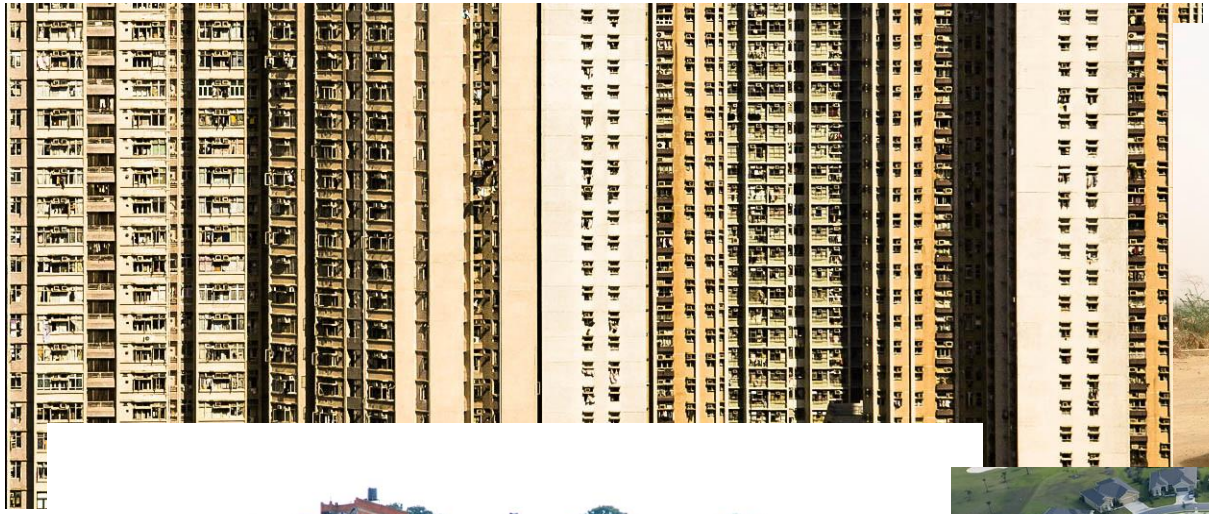
Risk - Confluence of Hazard, Vulnerability, and Exposure

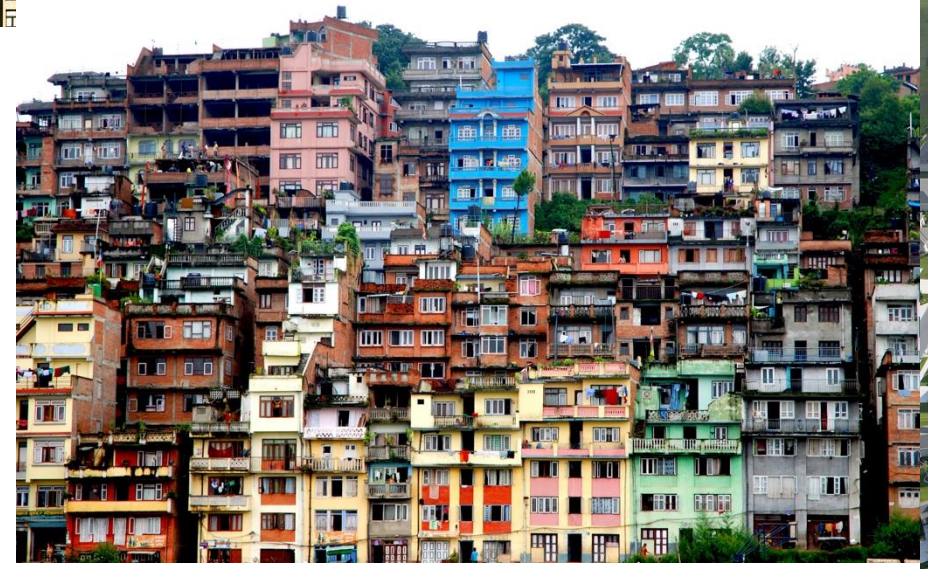


What is Building Exposure for DRR?

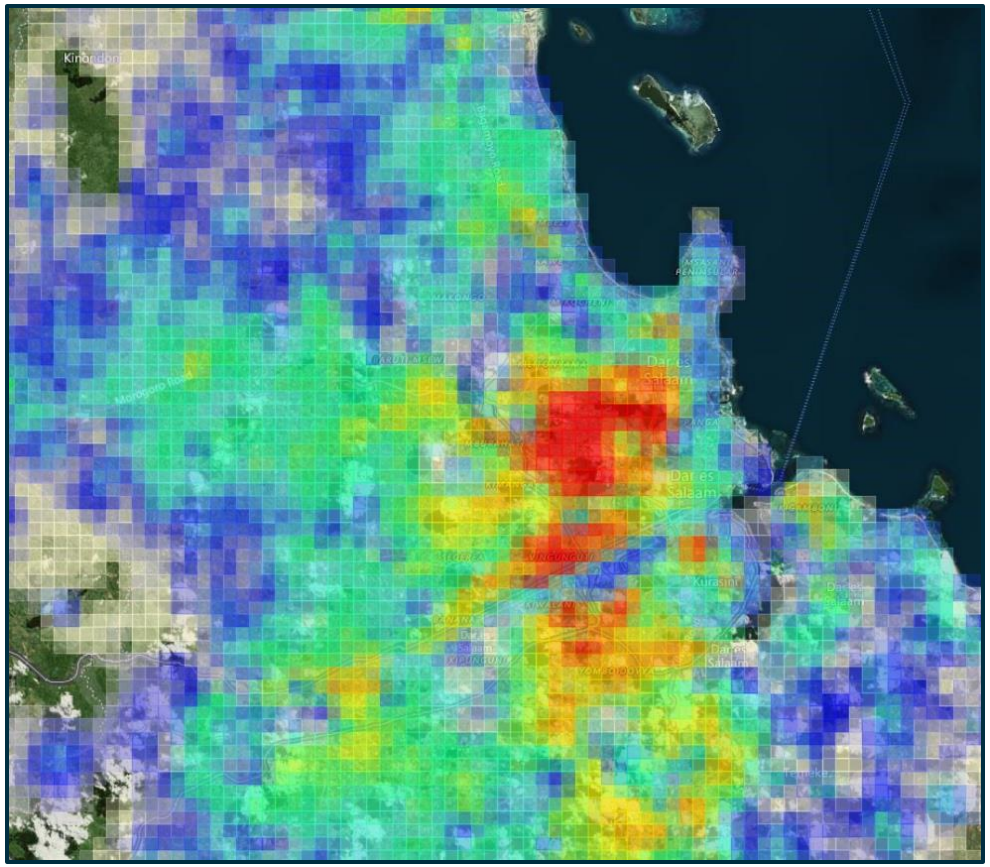


Number of buildings, where, by type and cost, for the purpose of assessing vulnerability and hazard proximity:





How is exposure data developed?



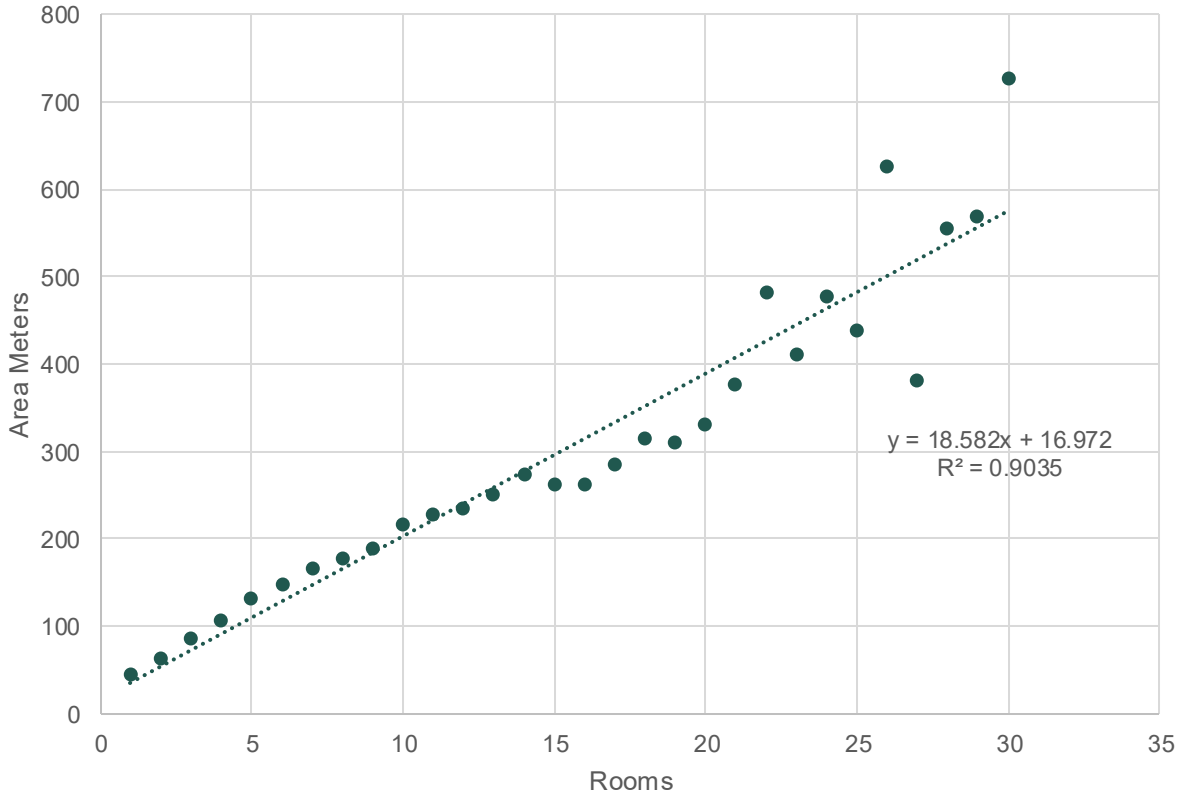
- Collect census data
- Estimate building attributes
- Refine spatial distribution
- Estimate number of buildings
- Estimate replacement value

Estimating Building Attributes

- Literature review of predominant building construction types
- Interpretation of EO
- Expert opinion
- Virtual reconnaissance
- Site surveys/stratified sampling
- Housing census

Estimating Number and Size of Buildings by Development Pattern

- People per household and households per building
- OSM (Open Street Map) building data footprint
- Microcensus or government reports
- Distribution of building area by story height
- Population density, urbanity, or EO metrics sometimes correlate

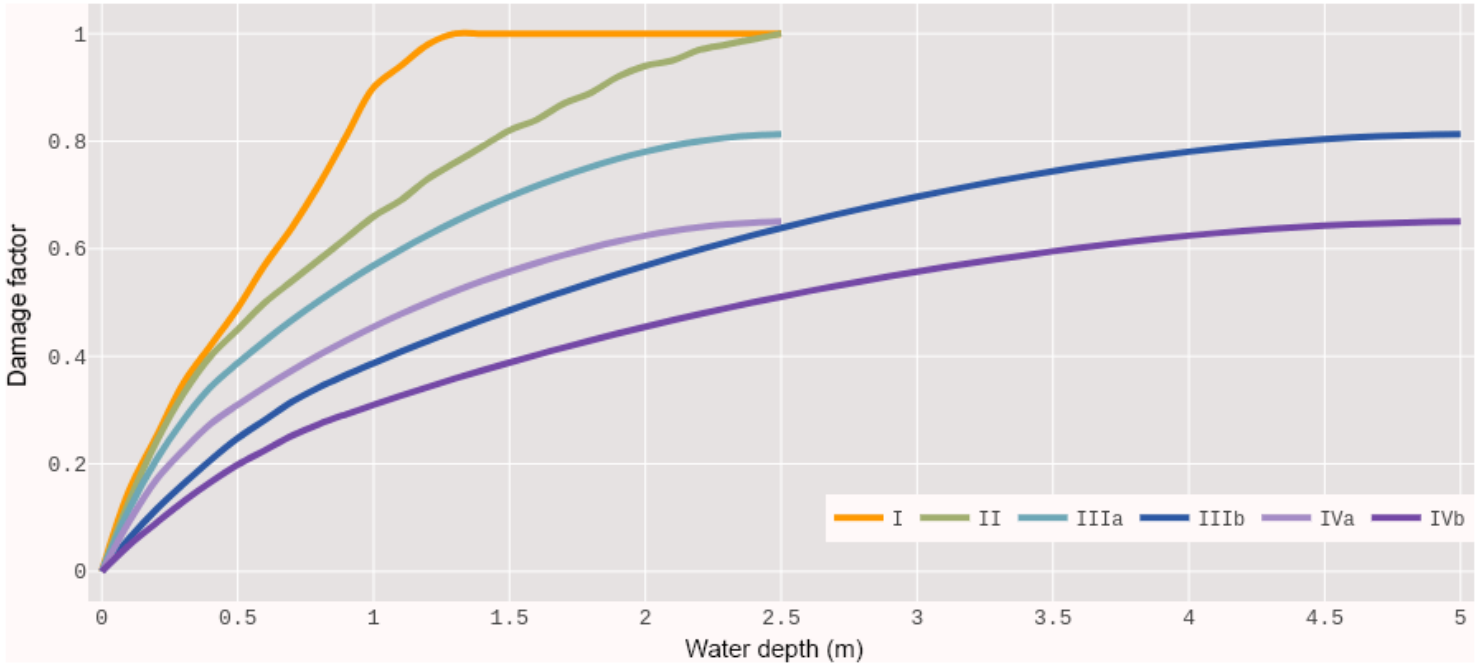


Estimate Replacement Value

- Building value per meter by building type or occupancy
- Building construction manuals
- Expert opinion
- GDP/median income
- Scale by building durability

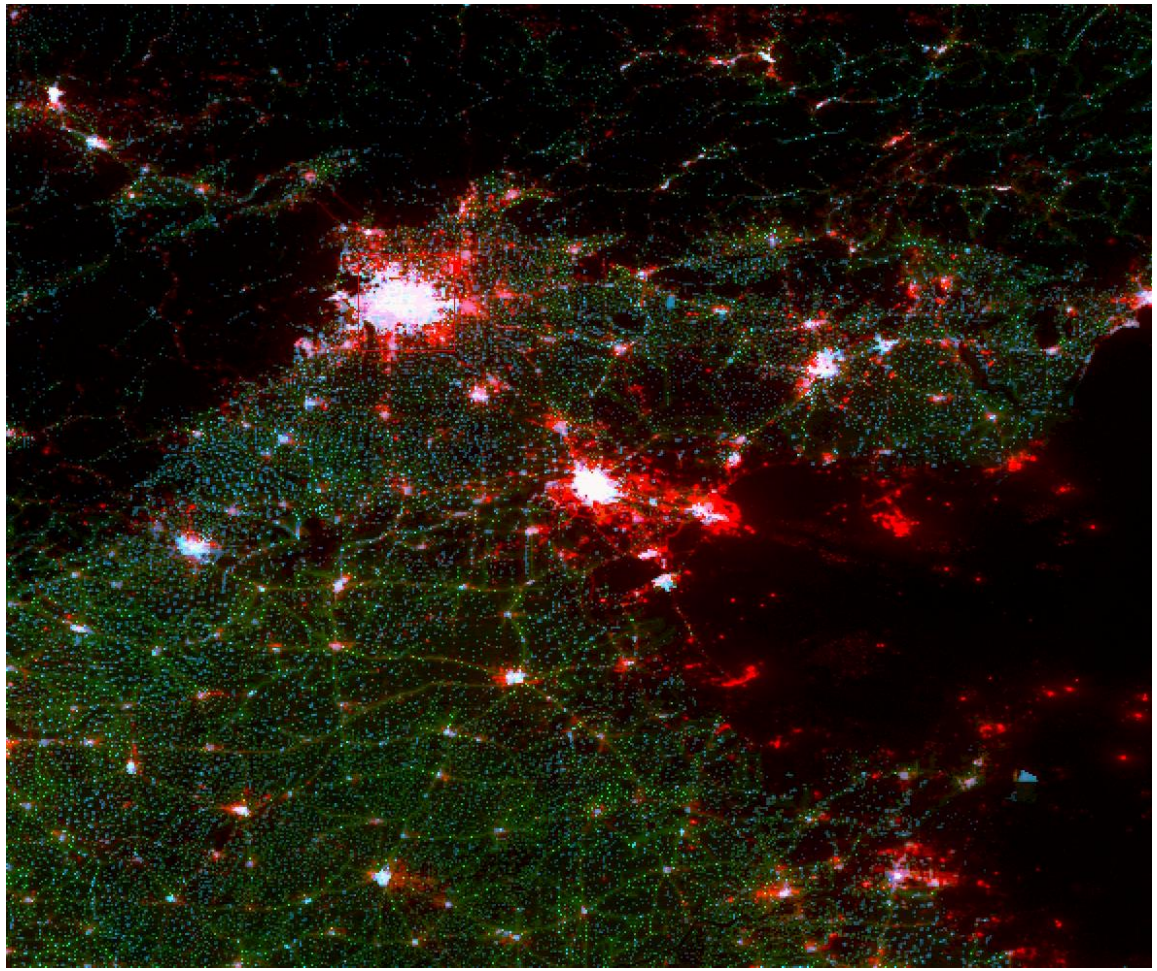
Building Vulnerability Attributes

- Era of development
- Number of stories
- First floor elevation
- Construction materials
- Lateral force resisting system
- Retrofitting
- Nail density
- Distance between buildings

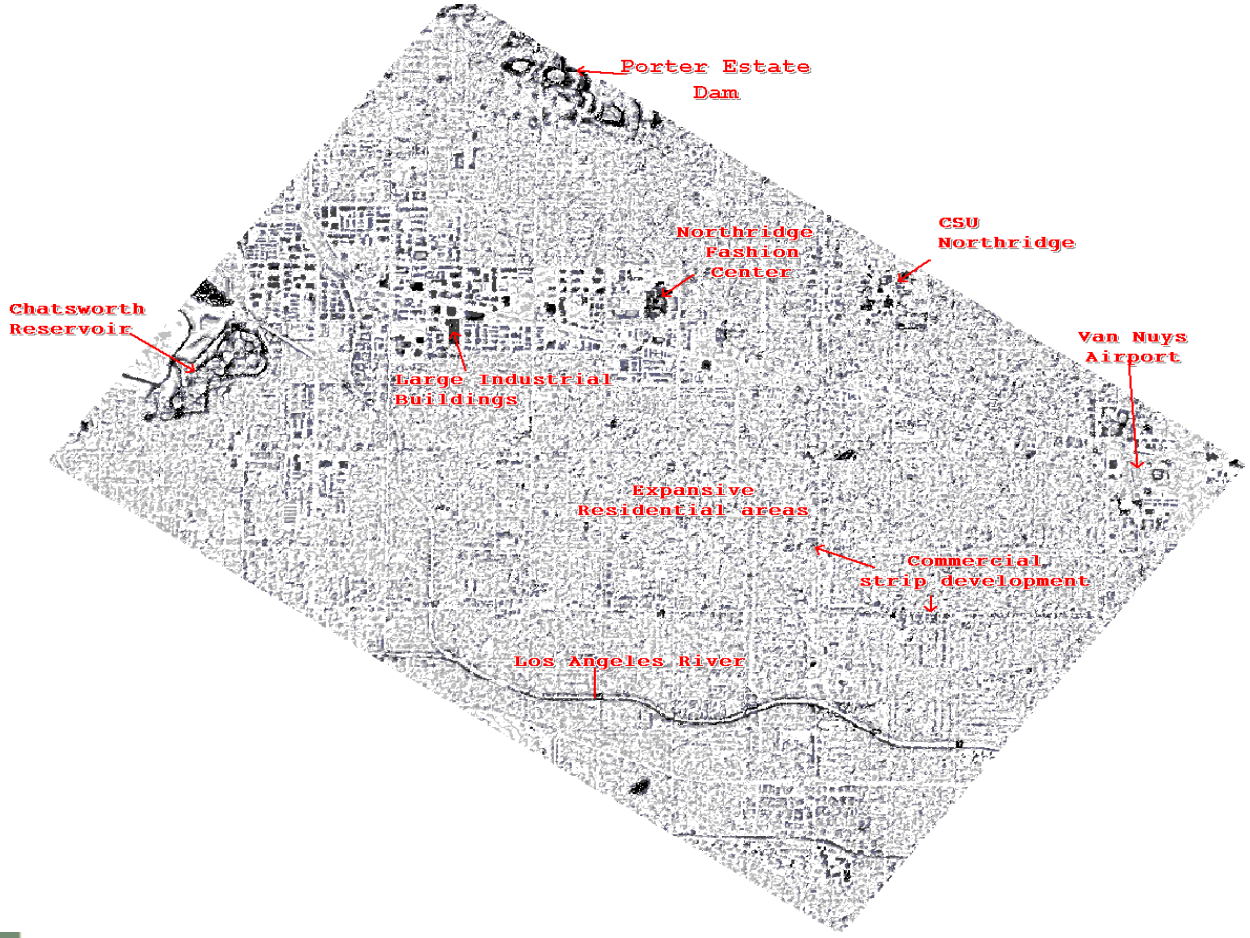


What is the role of EO in developing exposure data?

- Global population datasets
- Global urban/rural or urban intensity datasets
- Segmentation of development patterns
- Building footprint extraction
- Average building size
- AI, ground-based sensors

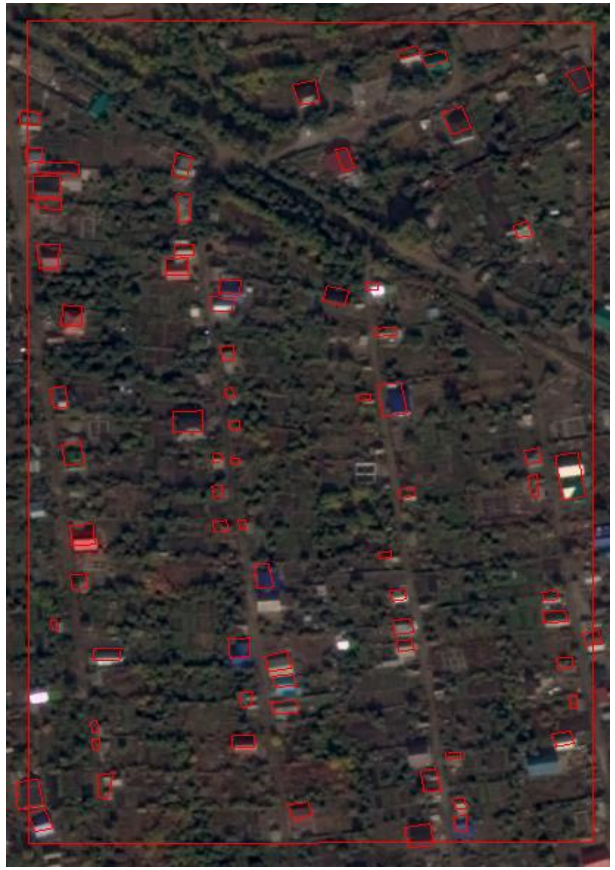


Building Footprint Extraction



Building Footprint Extraction

Rural



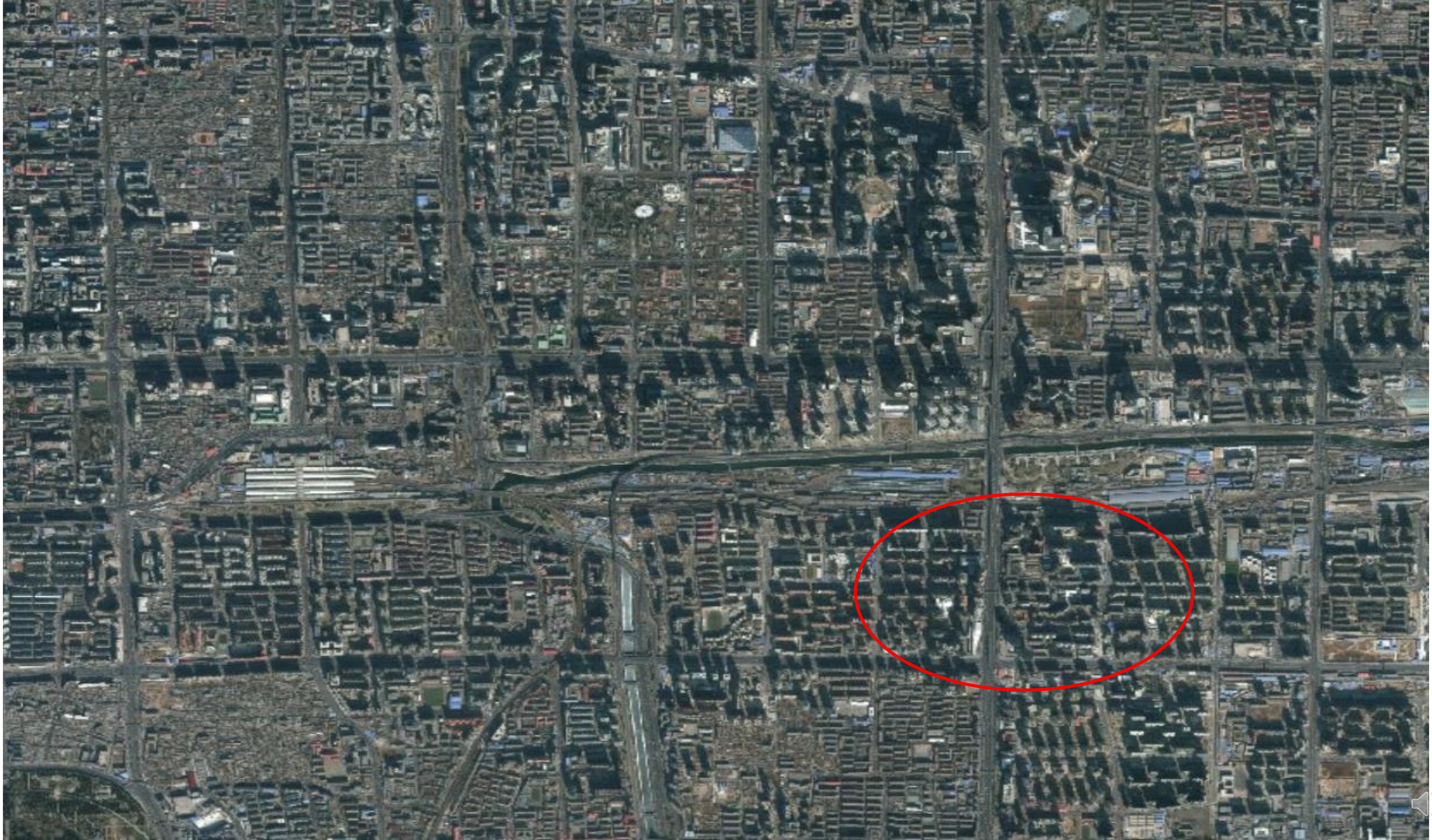
Residential

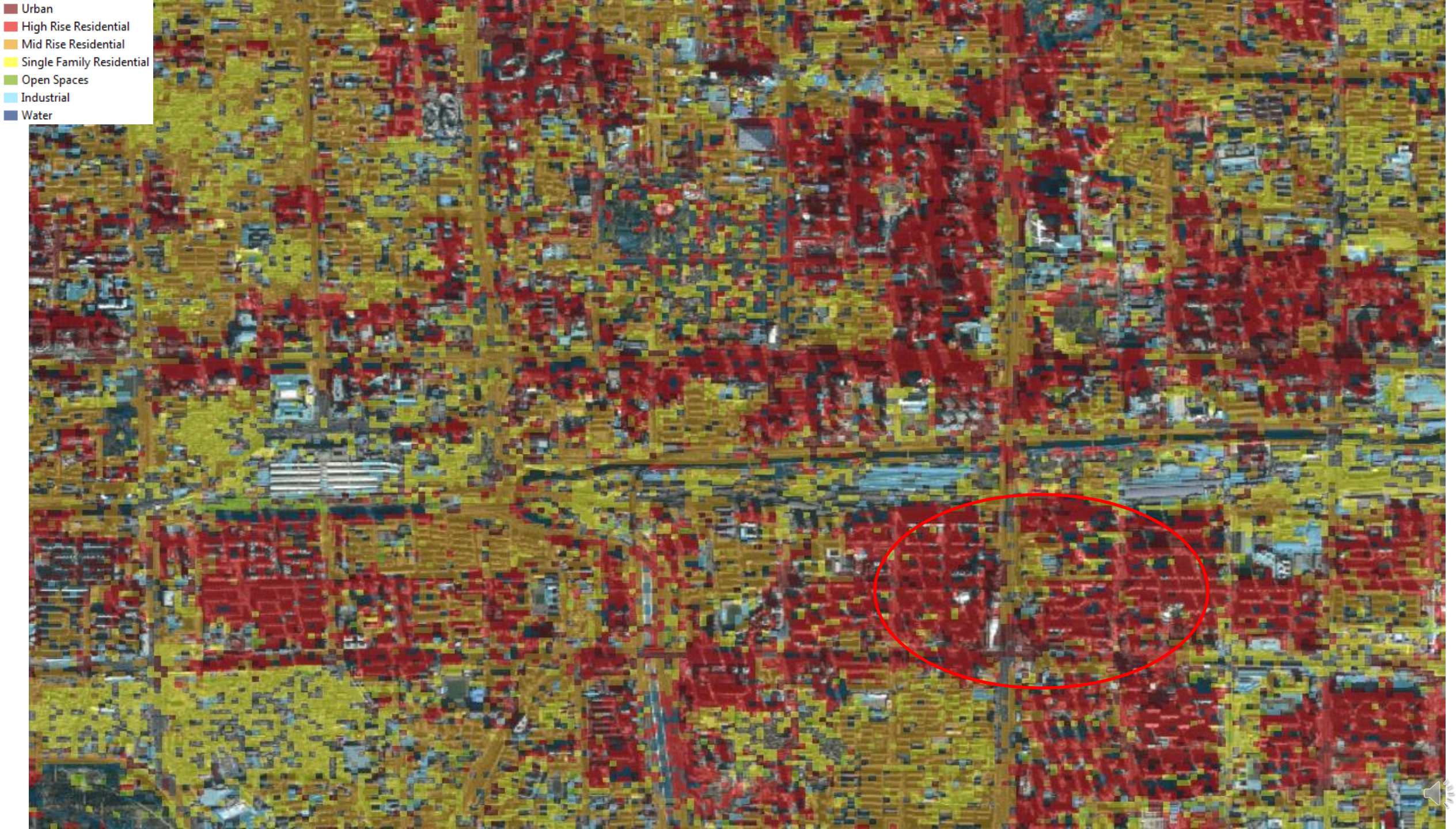
High Density Residential

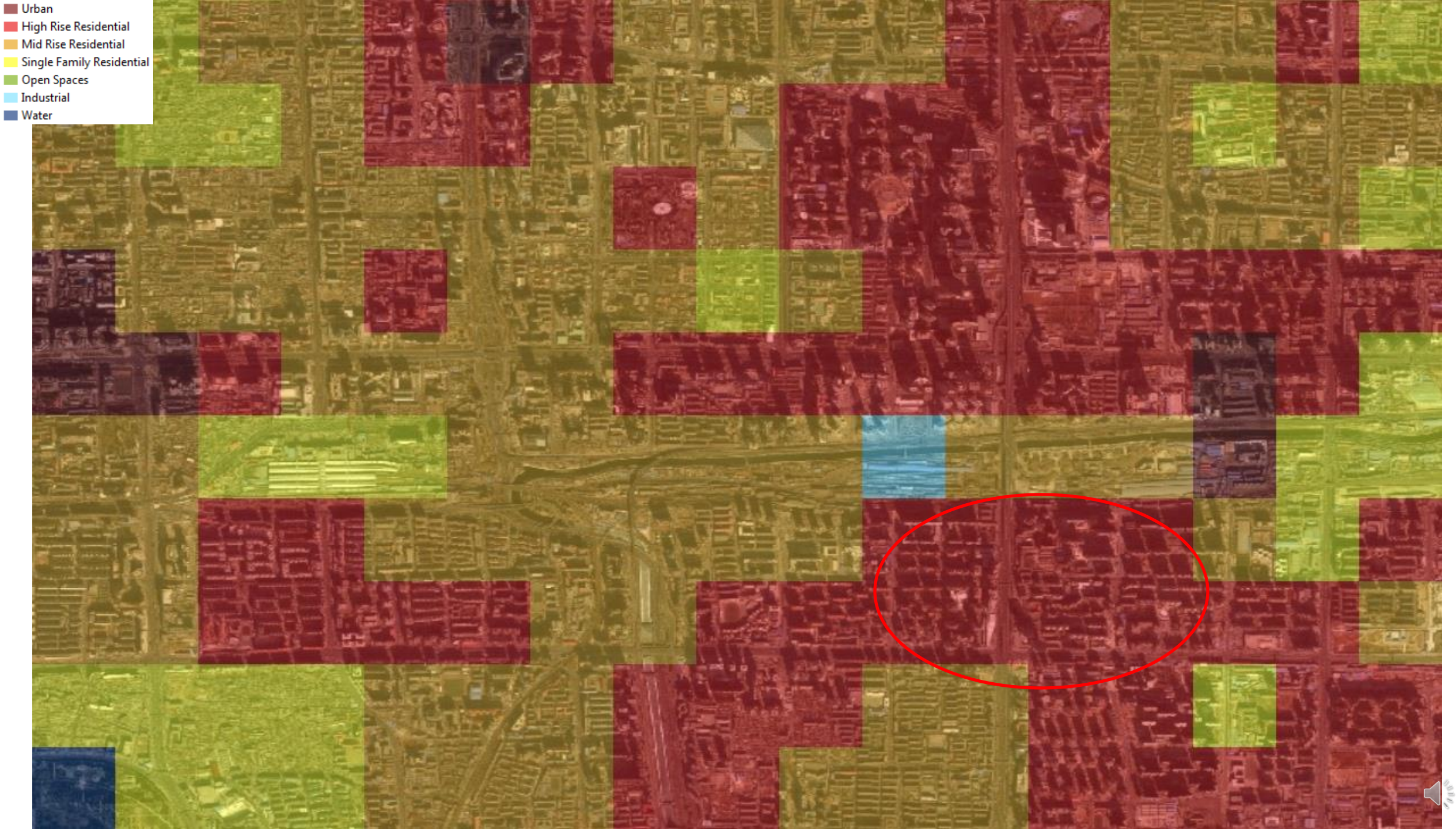
Extracting Development Patterns

Remote Sensing Example: Typical Midrise Residential in China

- Large residential apartments up to eight stories
- Typically constructed of unreinforced brick walls with concrete floor and roof diaphragms
- Observed RC frame with URM infill in newer buildings as well as typical Soviet Bloc construction



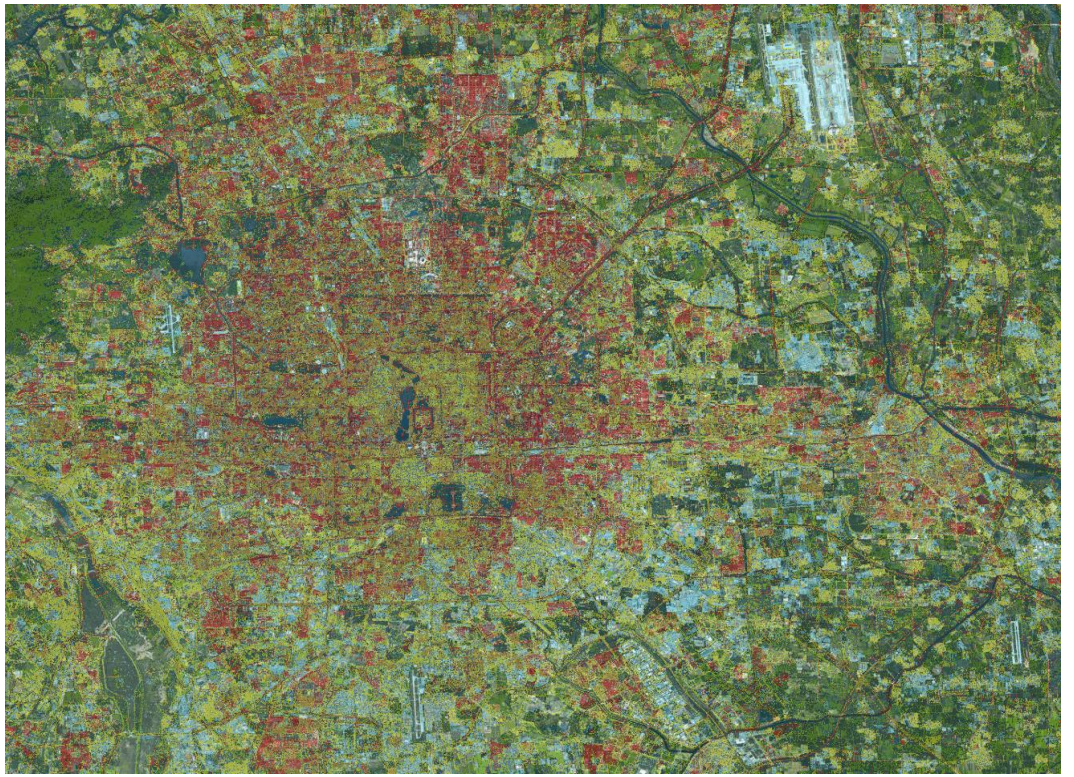

Urban
High Rise Residential
Mid Rise Residential
Single Family Residential
Open Spaces
Industrial
Water


Urban
High Rise Residential
Mid Rise Residential
Single Family Residential
Open Spaces
Industrial
Water

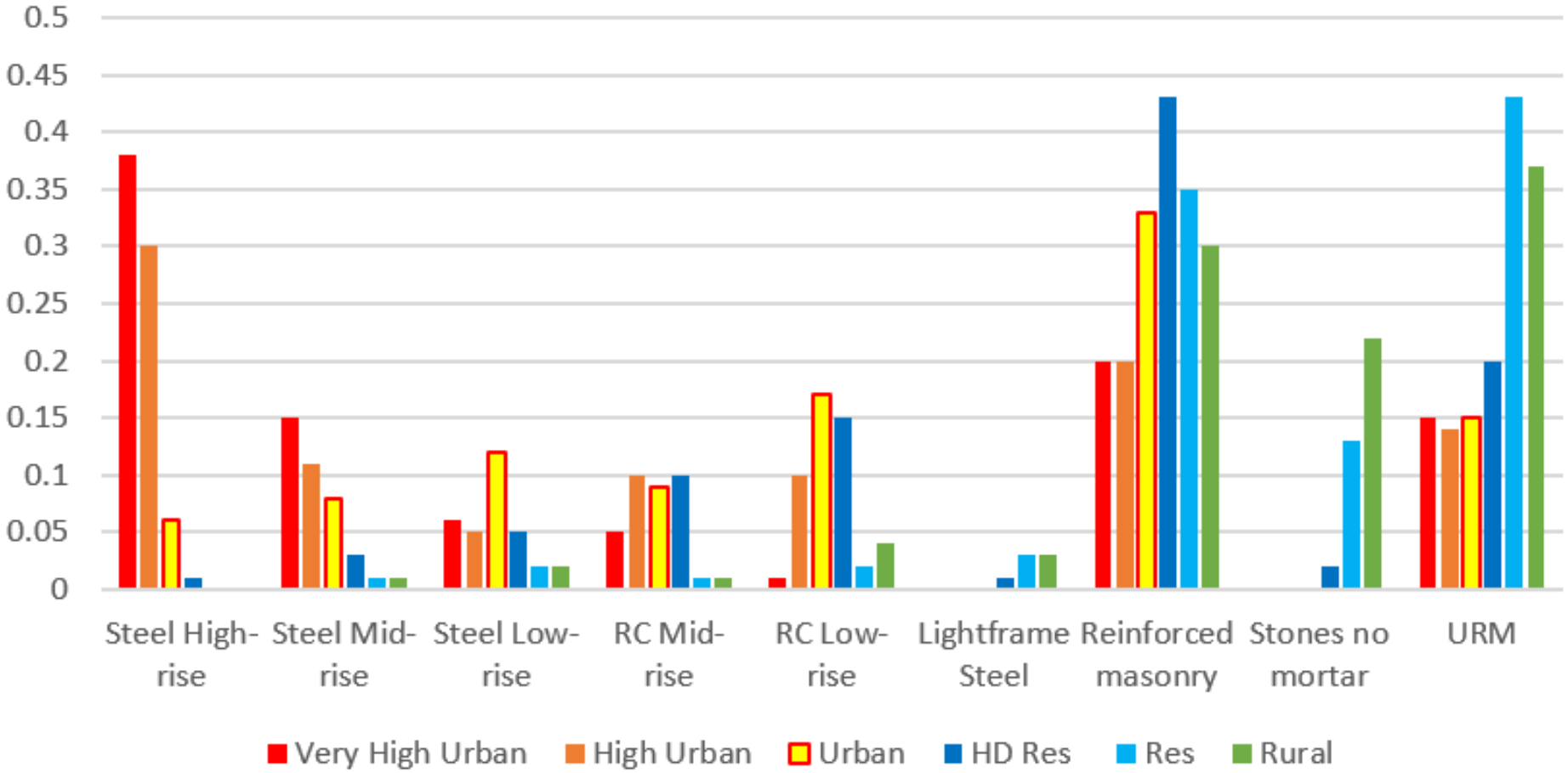
Extracting Development Patterns

More Accurate

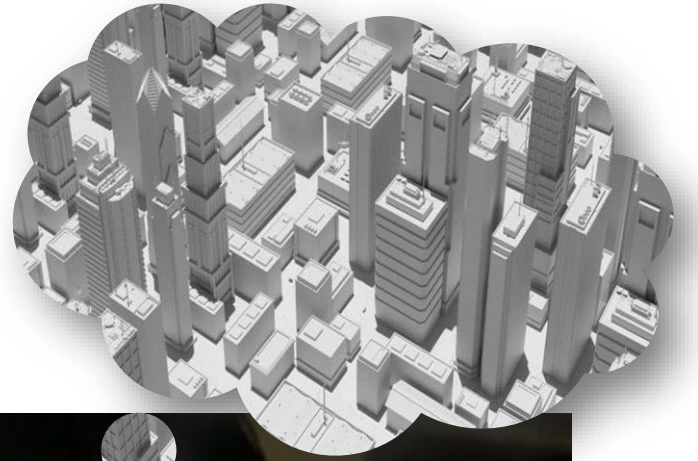
Higher Resolution

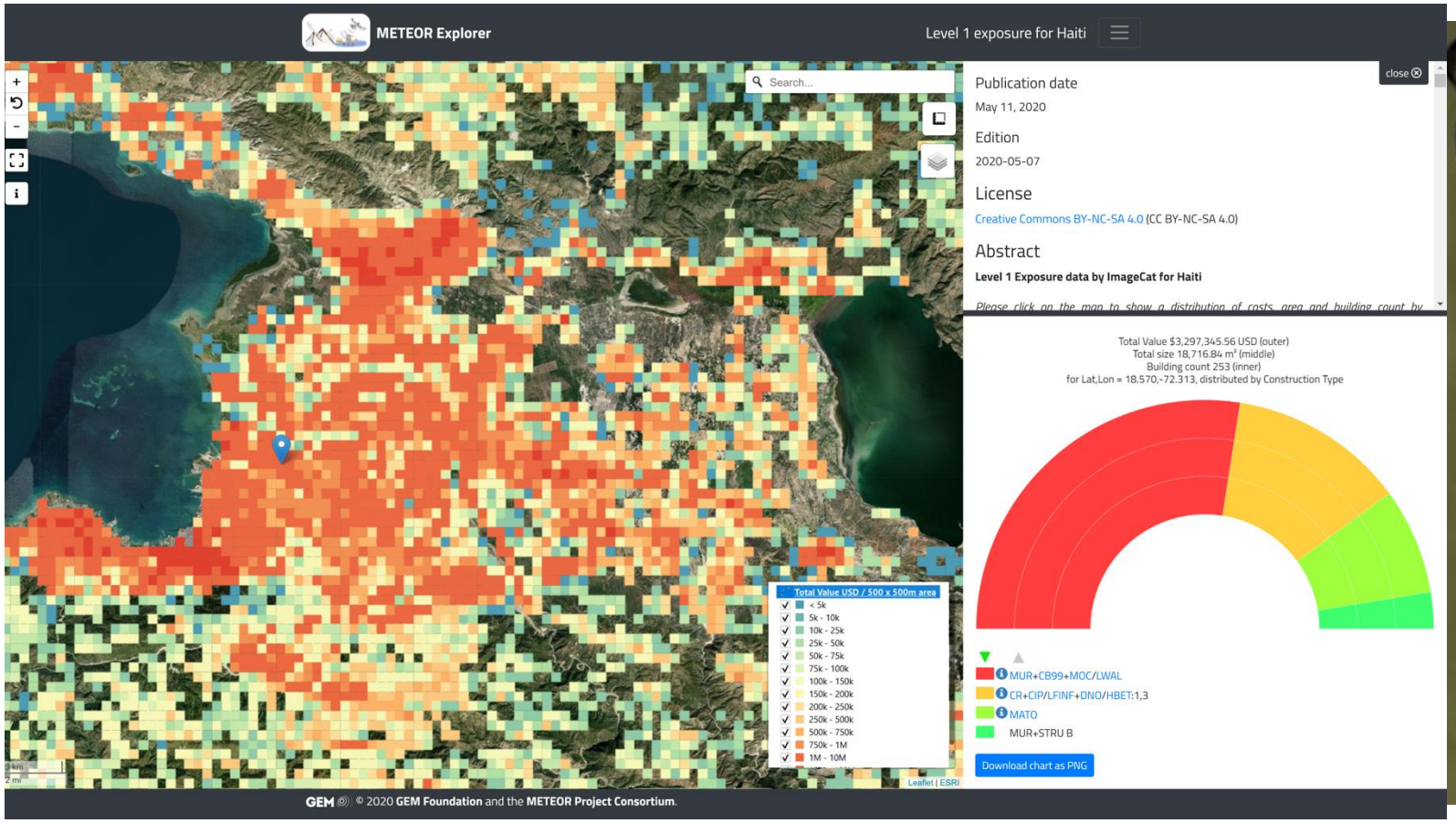


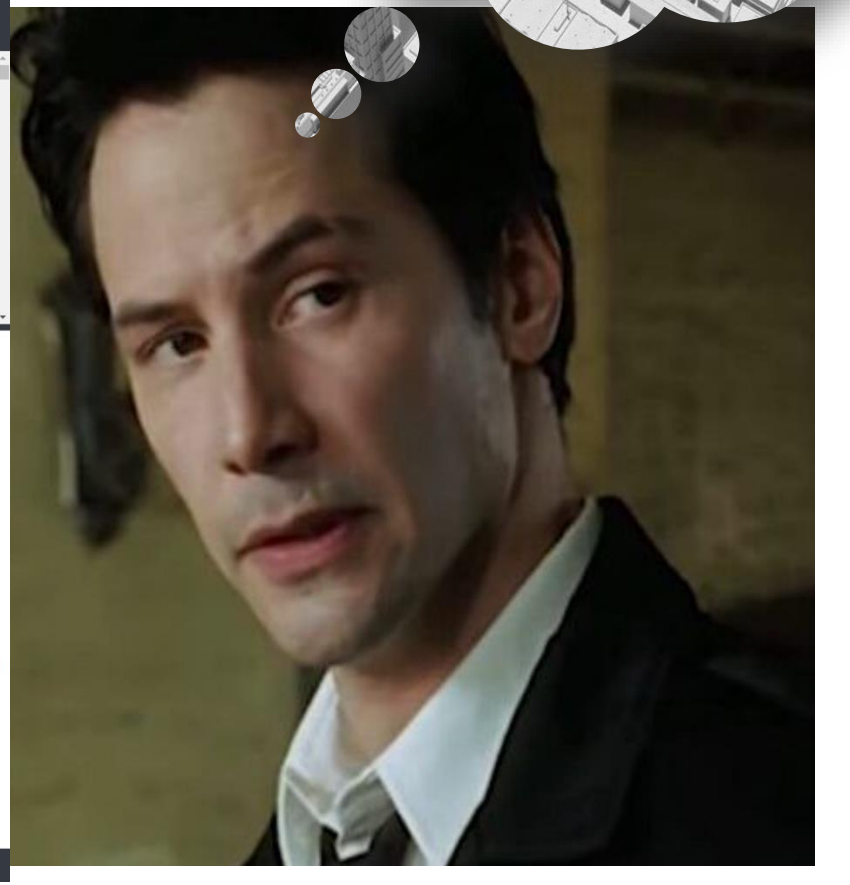
Merging Structural Characteristics with Development Patterns



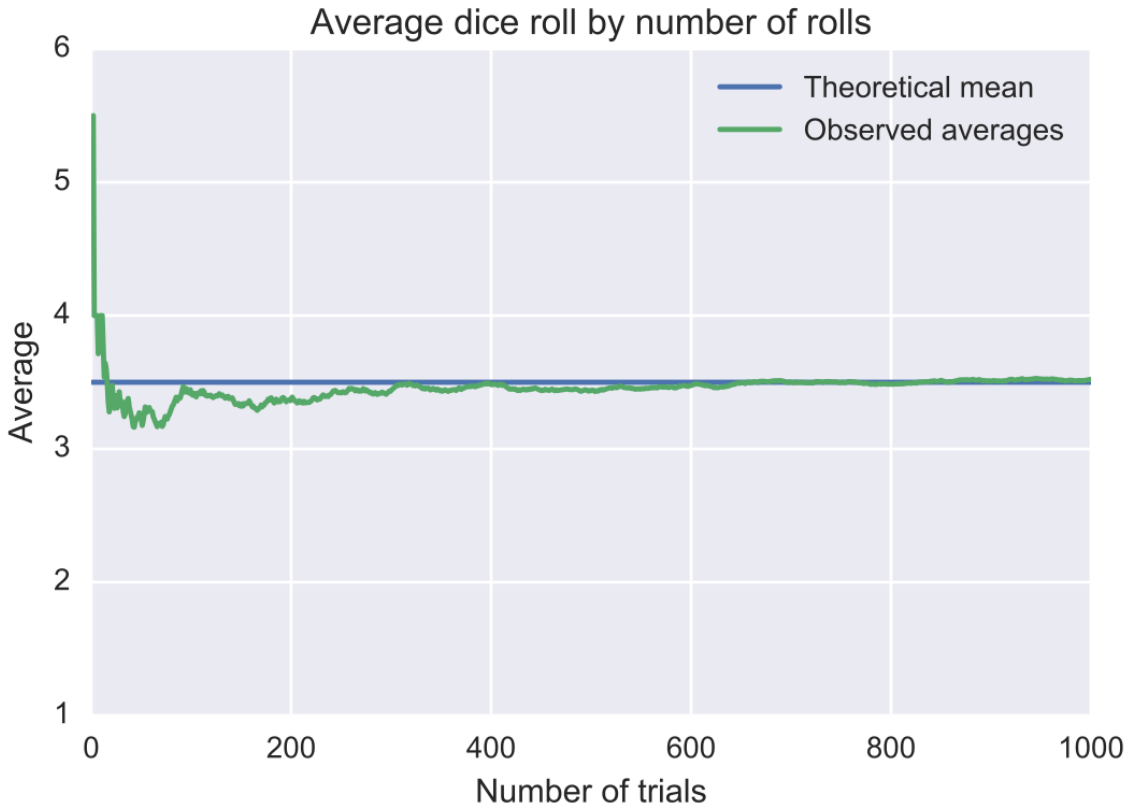
How good is this stuff?



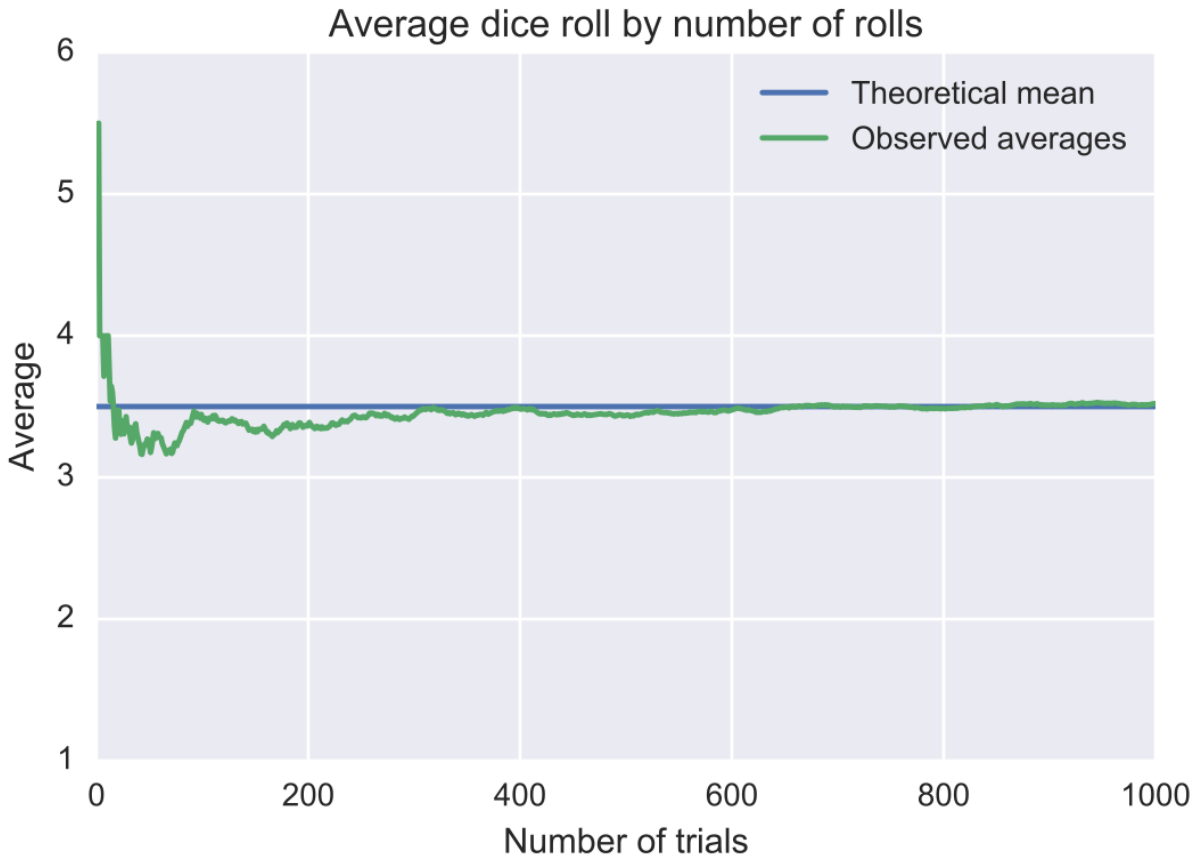




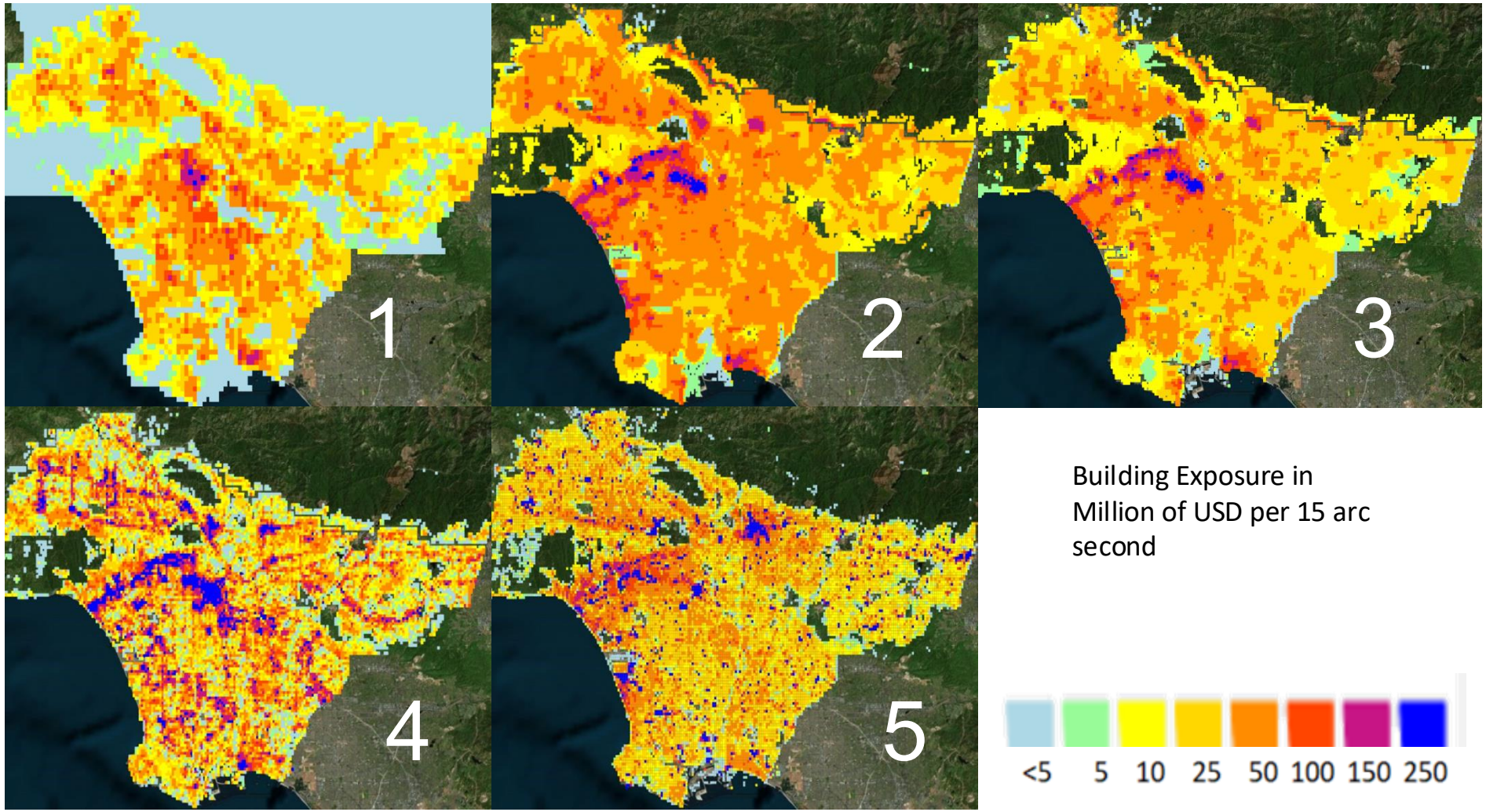
“Law of Large Numbers”



(Whoops!)

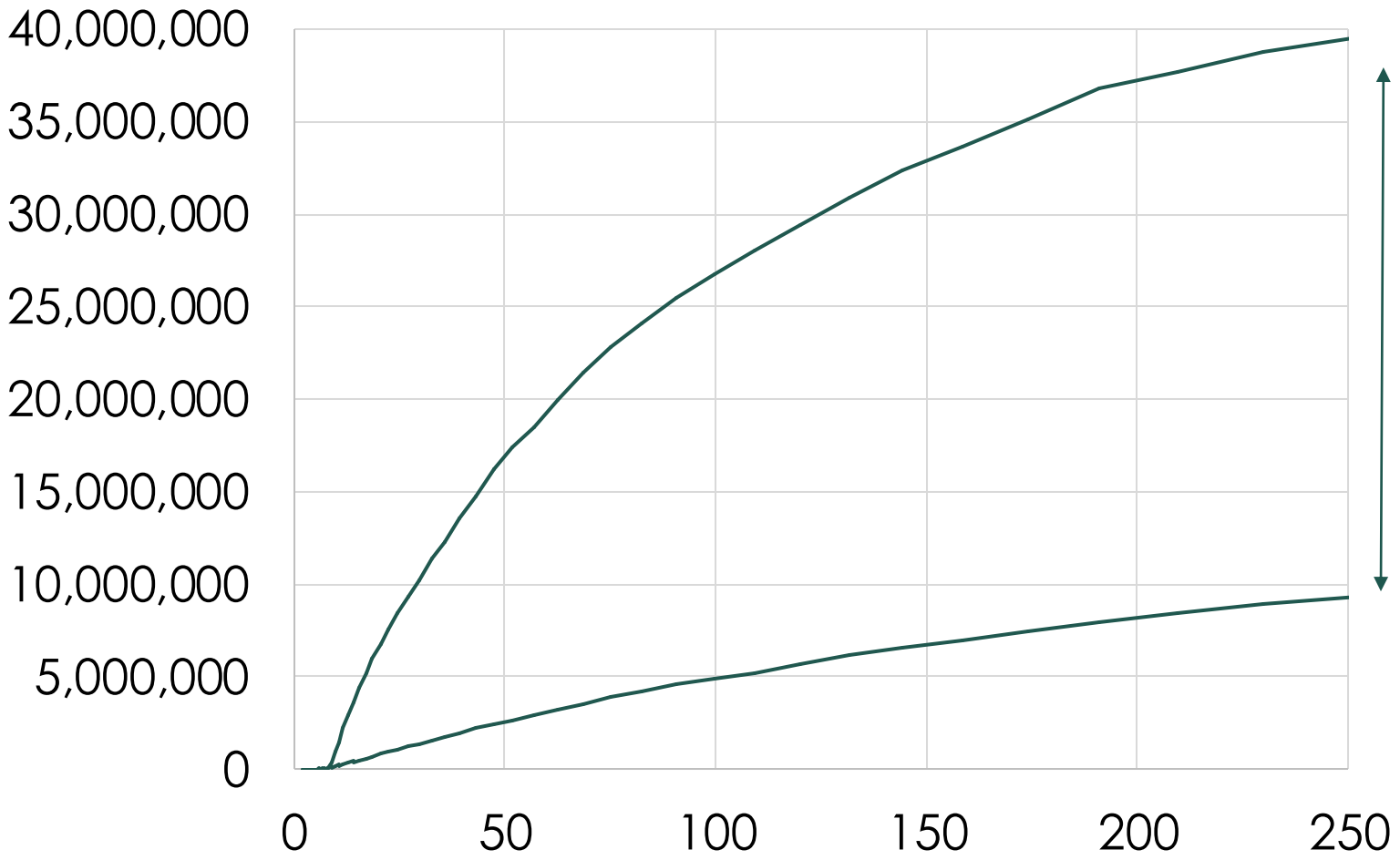

Average dice roll by number of rolls
Theoretical mean
Observed averages
Average
6
5
4
3
2
1
0
200
400
600
800
1000
Number of trials

Levels of Exposure Data



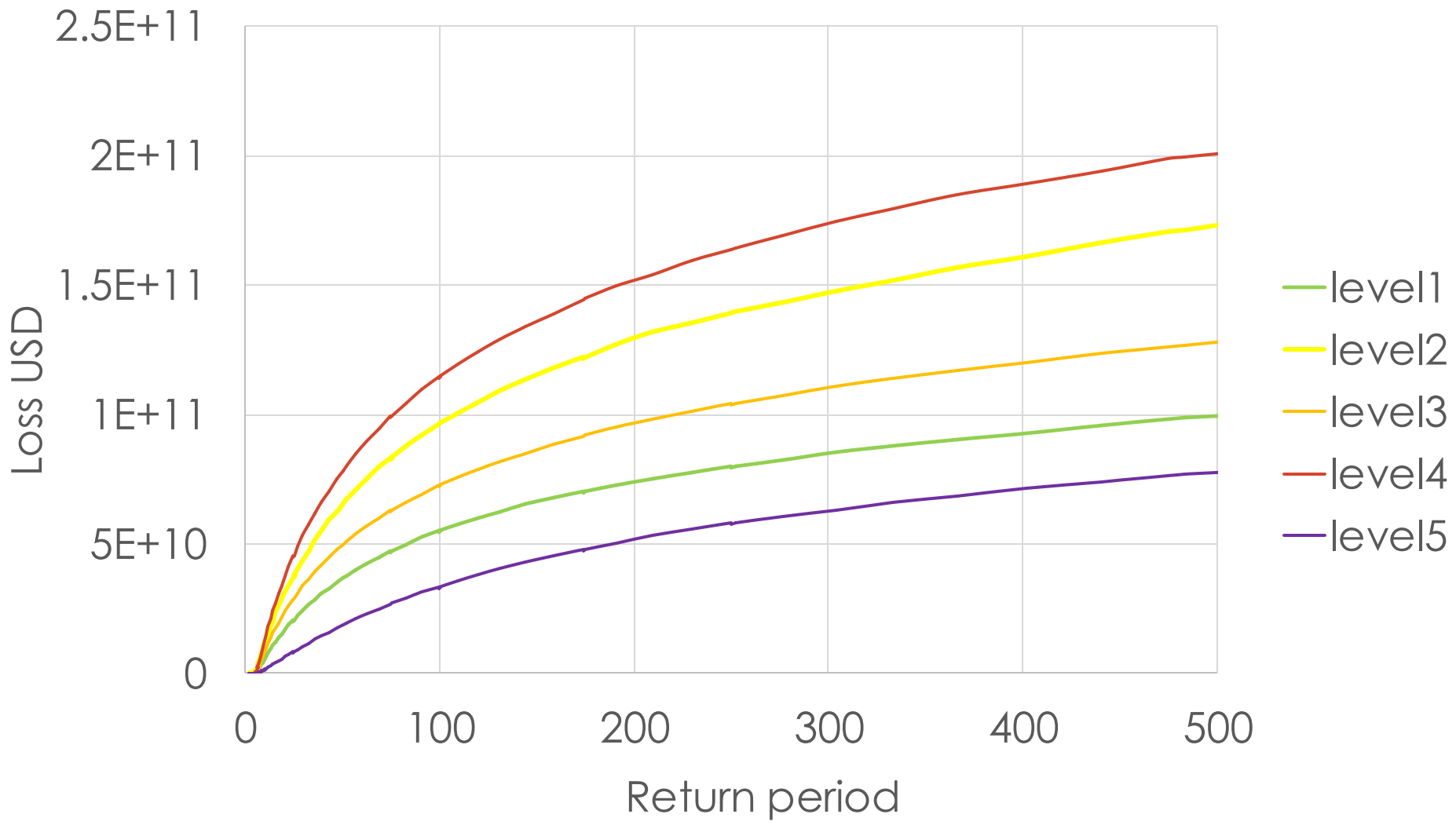
Building Exposure in Million of USD per 15 arc second

Levels of Exposure Data



Nobody knew!

Levels of Exposure Data



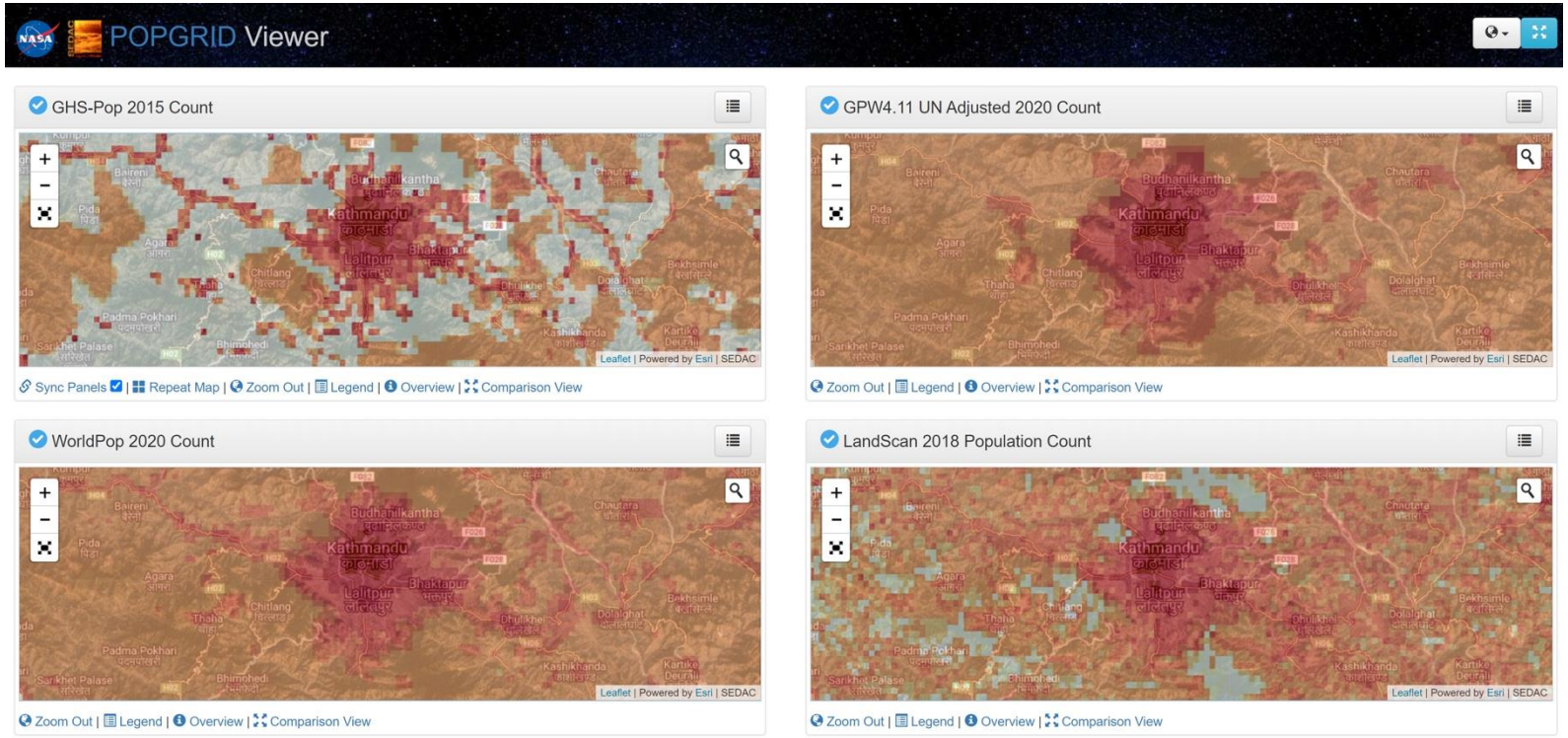
Key, Often Ignored Factors

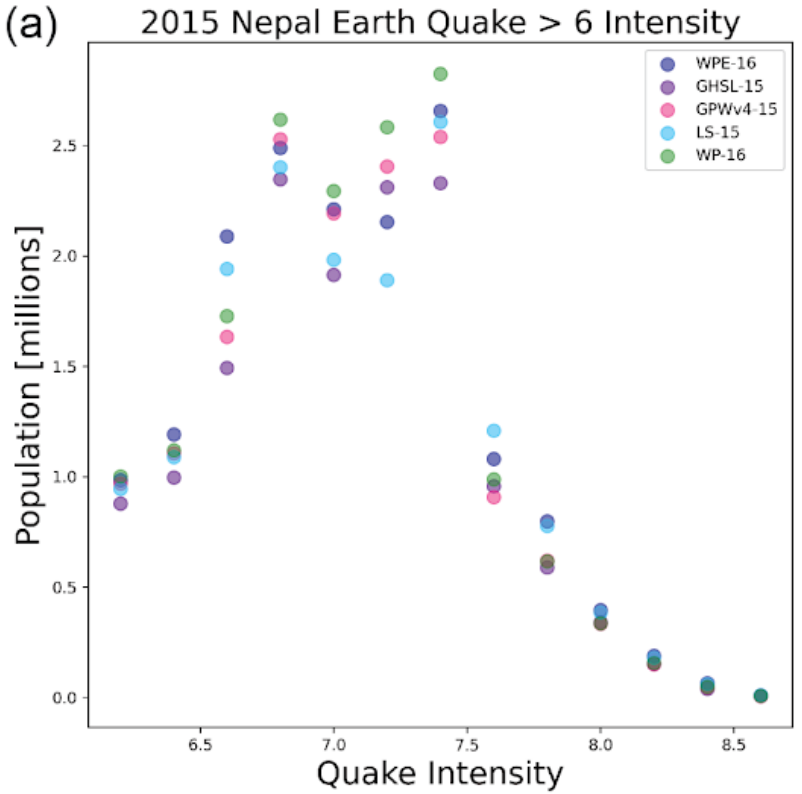
- Persons per household
- Living area per household
- Rebuilding cost
- Exchange rates

Focus:

- Vulnerability
- Geographic resolution

Global Population Datasets - Variance might not be critical for regional disasters.





Credit: Cascade Tuholske, PhD
Postdoctoral Research Scientist
Center for International Earth Science Information Network (CIESIN)
Earth Institute | Columbia University
www.tuholske.com

Extracting Development Patterns

More Accurate

Earthquakes and hurricanes

Higher Resolution

Floods and landslides, don't show client

Important to Address Expectations

Cannot typically expect accurate number of buildings at the cell level

Can expect more accuracy than in the original base data sets

Cannot expect to always capture small, unmapped rural areas

Challenges in remote sensing that will impact results (low lights, cloud cover, tree canopies, etc.)

Can not repurpose the data for civic purposes such as address-specific information for tax purposes

How much does it cost to build this hut?

Why does it matter?

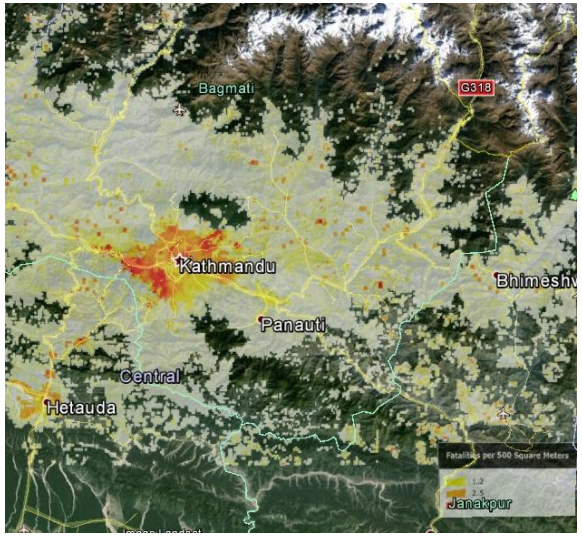
YES

Is it cost effective to retrofit certain types of buildings regionally?
Where should we focus retrofitting efforts?
Are building codes cost effective, and where?
What might happen after…
- A hundred-year flood
- A large earthquake
- A volcano

There has just been a large earthquake…
- What are the likely impacts?
- Where is likely to have been affected the most?
- How should we deploy resources?

NO

Is it cost effective to retrofit *this* building?
Which buildings fell down? Which homes are flooded?
Exactly how many buildings fell down?




APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!