Open Earth Observations for Sustainable Urban Development

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I. Introduction

Cities are where international development and environmental policy agreements[1] can have the greatest impact. They are the lifeblood of the engines that drive economic growth and have the potential to help realize the goals of sustainable development. According to the United Nations (UN), nearly 70% of the world's population will live in cities by 2050 (World Urbanization Prospects, 2018). This puts cities at the forefront in delivery of services and tackling the adversities of climate change through mitigation and adaptation measures. They are places where nature-based solutions and ecological or sustainable thinking can materialize through better urban design and planning.

Sustainable urban development requires action at all levels of administration — local, sub-national and national. This requires sufficient, spatially disaggregated data as the foundation upon which action towards national sustainability would need to be built. Resource constraints, coupled with only a 10 year runway remaining to achieve the SDGs necessitate strategic, evidence-based decisions that bring us closer to sustainability by 2030. As the movement among mayors and other local leaders to align local development with sustainability principles gathers momentum[2], the demand for cities' data is experiencing growth[3]. However, the supply is lagging. Increasingly, it is being recognized that Earth observation (EO) data can complement or enhance traditional data sources for cities and urban areas.

Which international agreements are relevant to cities?

1. **Sustainable Development Goals (SDGs) -** adopted by all UN Member States in 2015 as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030.
2. **New Urban Agenda (NUA) –** adopted at the Habitat III conference in 2016, it is a shared vision for a better and more sustainable future, one in which all people have equal rights and access to the benefits and opportunities that cities can offer, and in which the international community reconsiders the urban systems and physical form of our urban spaces to achieve this.
3. **Sendai Framework -** endorsed by the UN General Assembly after the 2015 3rd World Conference on Disaster Risk Reduction, the framework is a call to action for member states to reduce disaster risks in collaboration with local governments and other relevant stakeholders.
4. **Paris Agreement –** is a 2016 agreement within the UN Framework Convention on Climate Change (UNFCCC) dealing with greenhouse gas emissions reduction and finance.

To be able to generate timely, reliable and disaggregated data on the 232 indicators in the SDG framework, PARIS21 finds the need to double the financing for data and statistics to ensure that the "SDGs leave no-one behind" (PRESS, 2019). This estimate is based on the data needs for reporting on national SDG progress. Data needs of cities for forward planning, monitoring local development and reformulating local policies imply additional financing needs beyond those estimated by PARIS21.

Urban planning and land management data does not typically come from national sources. These are data that cities and municipalities often generate themselves - either in real-time, or regularly or as needed. Some examples of such data generating activities are – cadastral surveys, land use surveys, topographical surveys, transportation and traffic surveys, air quality monitoring, and ground and surface water monitoring. To complement this information, national statistical systems such as censuses and sample surveys, provide urban demographic and socio-economic data. Other relevant national sources of data include meteorological departments, geography and geology department surveys.

Efforts are underway to strengthen the national statistical systems[4] through international resource mobilization and increasing national budgetary allocation. However, other data, i.e. geospatial data, that is used by cities for forward planning and land management has not received much attention and remains a challenge to find. There are three key reasons for this: (i) the cost of generating this data through traditional methods remains high; (ii) the technical capacity in geospatial sciences in many countries is low. There is a shortage of skilled professionals who can find and/or process available data; and (iii) the inertia against disturbing routine workflows and adopt new practices that are not imposed through legal requirements at the country level. Earth observations data and engagement with the global geospatial community can help overcome the first two challenges. The third challenge requires continued advocacy efforts to build political will.

[1] These include the Sustainable Development Goals (SDGs), New Urban Agenda (NUA), the Sendai Framework and the Paris Agreement.
[2] We are seeing many cities in developed countries align their planning and visions to the SDG agenda and create their own contextually relevant set of sustainability goals. Cities in developing countries are also committing to achieving the NUA.
[3] This is particularly visible in Europe, but developing countries are also coming onboard. For instance, the SMURBS program partners with cities to generate relevant and useful data using Earth Observation based on the needs of cities. For more information, see: https://smurbs.eu/
[4] The 2030 Agenda for Sustainable Development recognizes the need for indicators to be disaggregated, where relevant, by income, sex, age, race, ethnicity, migratory status, disability and geographic location. Without this geographic disaggregation, information is of little policy relevance beyond monitoring the SDGs at a high-level. Geographic disaggregation was included in the agenda to provide knowledge of hotspots where policy interventions are required to make inclusive progress towards the globally agreed goals and targets. For further information on which indicators need to be disaggregated, see: https://bit.ly/31t3EHX

II. Earth Observations: How is this data being used by city leaders?

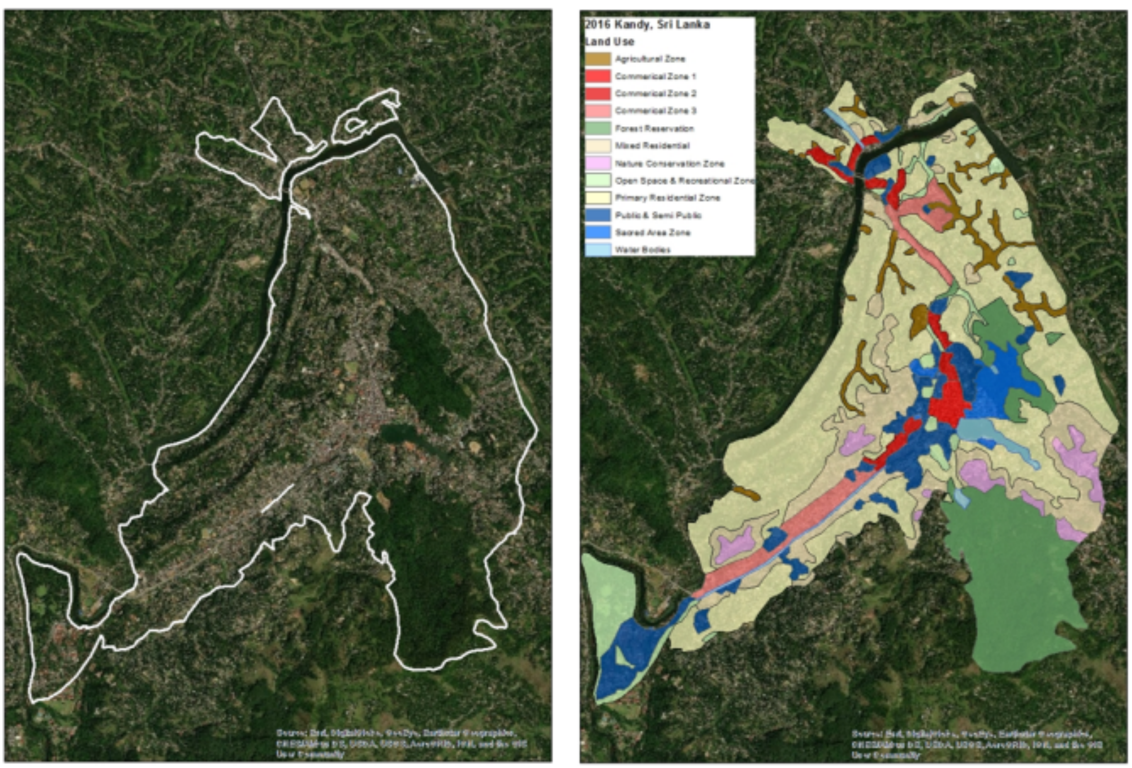
Earth observations (EO) are data and information about the planet's physical, chemical and biological systems. It involves monitoring and assessing the status of, and changes in, the natural and man-made environment. In recent years, Earth observations have become more sophisticated with the development of remote-sensing satellites and increasingly high-tech in situ instruments that measure on the ground data. Today's Earth observation instruments include floating buoys for monitoring ocean currents, temperature and salinity; land stations that record air quality and rainwater trends; seismic and Global Positioning System (GPS) stations; drones for capturing high resolution images in small scales; and high-tech environmental satellites that scan the Earth from space.

EO is now more important than ever due to the impacts of human civilization on the global environment. EO data, whether atmospheric, oceanic or terrestrial, are already helping decision makers around the world to better understand the issues they face and shape more effective policies aligned with local goals. EO data can be used to support national statisticians, chief data scientists, chief data officers, ministers of planning, or others concerned with evidence in support of sustainable development (SDSN, 2019).

With advances in space-based instruments, EO capabilities have also seen a substantial increase in the range of information they can provide for decision-making. Tracking atmospheric conditions, measurements of vegetation and land use/land cover, estimating population densities and the scale of electrification are just a few drops in the ocean of applications. However, the greatest value proposition of EO data is its continuous spatial-temporal coverage at a fraction of the cost of traditional methods, while ensuring objectiveness, comparability as well as sustainability of services. This value proposition led world leaders to acknowledge the important role that EO has to play in making the SDG framework "feasible through the provision of essential evidence, including the tracking of indicators over time, and supporting the implementation of solutions to reach specific targets" (GEO, 2017).

Similar to the value identified by national leaders, EO also poses great opportunities for leaders at the local level. Land use mapping, topographic mapping and other useful information for cities can now be generated using high-resolution[5] satellite imagery at low cost. High-resolution imagery, when analyzed, provides sufficient detailed information and reliable data can be generated about areas as small as a single housing unit. For example, the city of Kandy in Sri Lanka, with the support of the World Bank, developed various land use maps to take stock of its current land consumption and associated activities (see: **Fig 1**).

Fig 1: Land use map of Kandy, Sri Lanka in 2016 drawn using remote sensing



Source: World Bank

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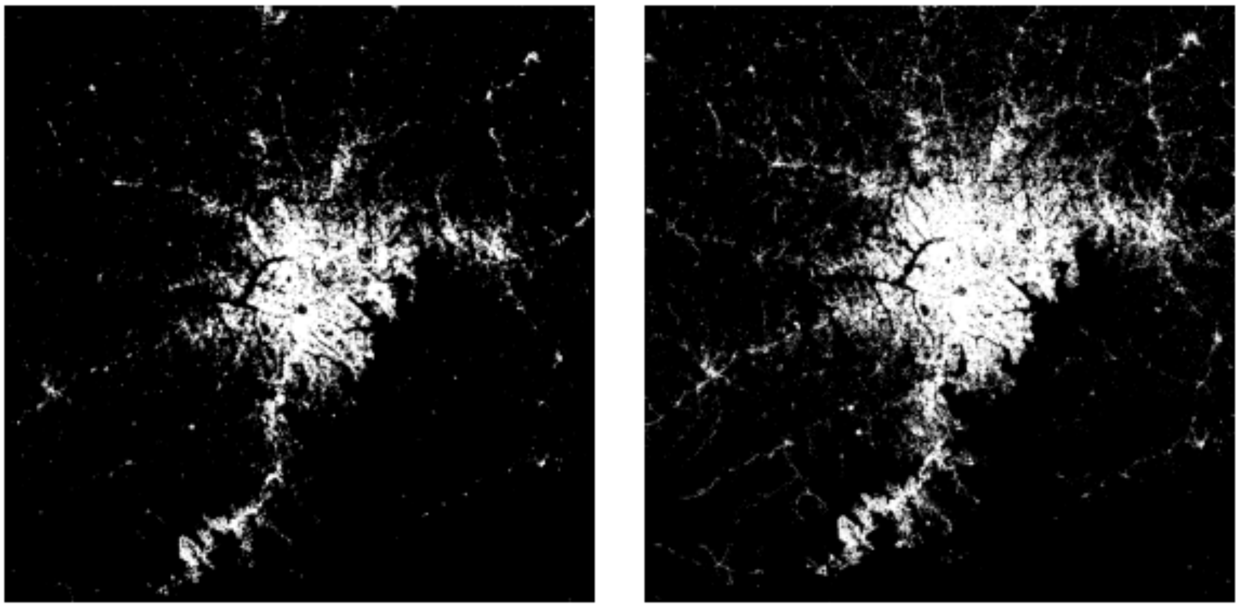
[5] Spatial resolution is a measure of the level of detail captured by an image. It refers to the size of the smallest feature that can be detected by a satellite sensor. Satellites such as WorldView-4 can now offer capabilities of capturing any object that is as small as 30cmx30cm. Images that can capture smaller objects are typically referred to as high-resolution.

Nonetheless, urban monitoring need not just rely on the use of high-resolution satellite imagery. Medium-low resolution images (15m-30m) also offer valuable insights that are useful for urban managers and decision makers. For example, Kampala, Uganda used medium-low resolution imagery to monitor the overall growth and direction of sprawl of its built-up areas[6] (see: **Fig 2**). Information on land use change and spatial growth rates and direction can inform city leaders on areas that require administrative attention, for example, to regulate construction and avoid encroachments on public land, channel resources to create supporting infrastructure, estimate demand for services and conserve ecologically sensitive areas.

Fig 2: Urban extent changes in Kampala, Uganda between 2002 and 2014

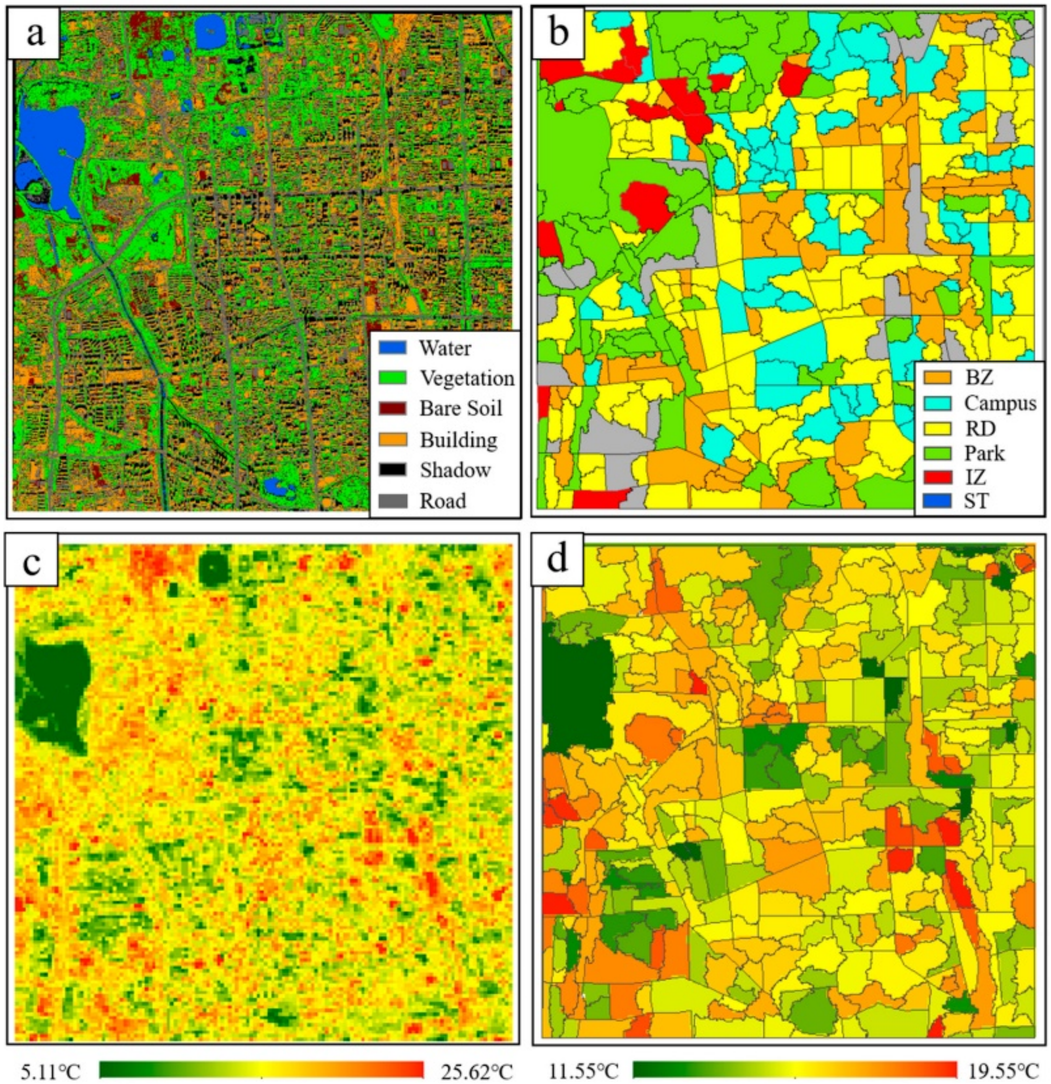


Source: GEO, 2017

EO also has applications for gathering data on environmental attributes of cities. For example, urban planners and environmental scientists continue to use remotely sensed information as a way to measure land surface temperatures at scale to inform policies on target areas within the city that require mitigation measures, such as urban greening, to tackle challenges associated with the *heat island effect* (see: **Fig 3**). Surface temperature readings can be combined with other measures of weather such as precipitation, soil moisture and surface water quality or quantity over time to develop predictive models that allow for future-proofing urban development. This is particularly relevant for cities grappling with the effects of climate change, such as sea level rise and urban flooding.

[6] The European Space Agency's Copernicus program is working on providing similar built-up area maps for all cities worldwide with at least biannual updates starting in the year 2021. The program will also release the World Settlement Footprints dataset, using Sentinel-1 and Landsat data that will have information on the urban footprint of all settlements in 2015. The World Settlement Footprints dataset will be available in summer 2020.

Fig 3: Urban heat island mapping in Beijing, China



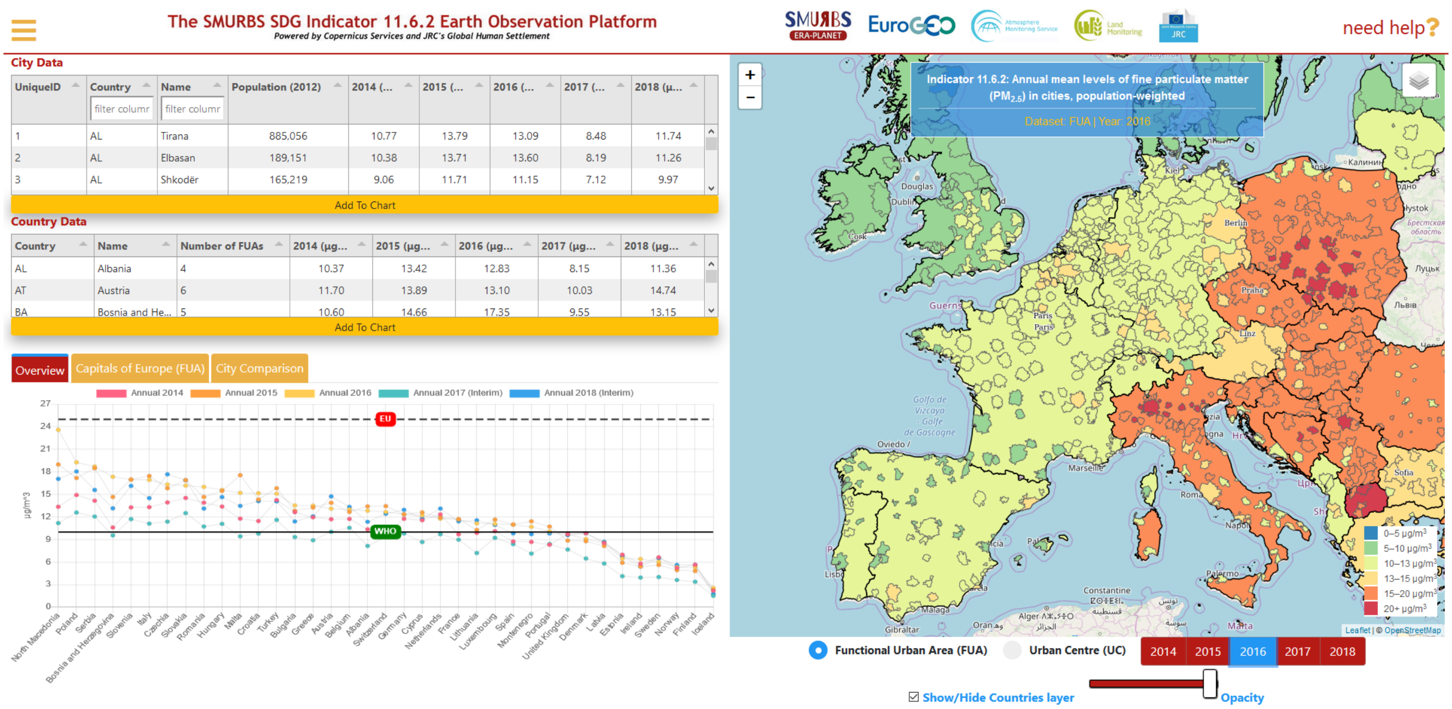
Source: Feng et. al. (2019). Retrieved from: https://bit.ly/38a2rrC

Using EO to track and report on international agreements at the city level

City leaders that adopt the international frameworks of sustainable development in their jurisdictions can use EO to track and report progress on many of the global indicators. For example, indicator 11.6.2 of the SDG framework that tracks annual mean levels of fine particulate matter in cities[7] (also referenced in paragraphs 13, 55 and 67 of the NUA) has traditionally been monitored through ground-based measurement instruments, which many cities in developing countries may or may not have. Earth observation can unambiguously assist in this measurement to be done at scale (see: **Fig 4**).

[7] For further information, see SDG indicator 11.6.2 metadata available at: https://bit.ly/39bYy5I

Fig 4: The online platform created by SMURBS/ERA-PLANET H2020 project for monitoring SDG indicator 11.6.2 (mean annual levels of fine particulate matter in cities, population-weighted) in Europe



Source: SMURBS[8]. Retrieved from: https://bit.ly/2SnM9EM

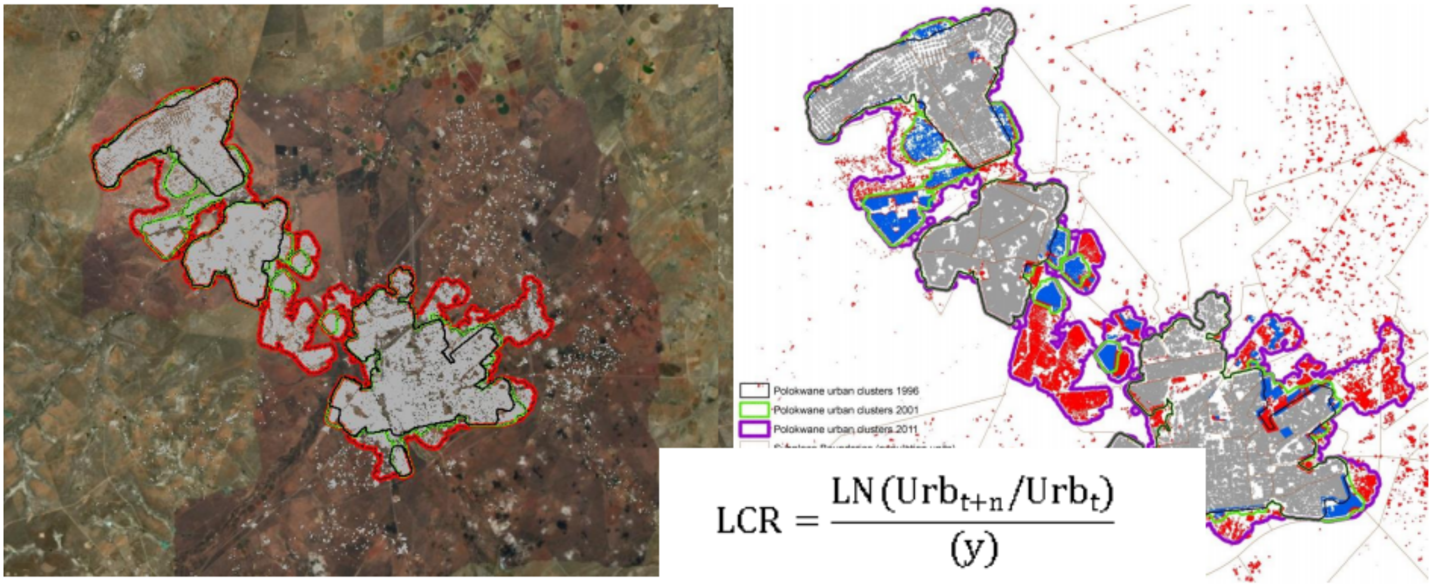
EO can also help in tracking other SDG indicators that are relevant to city-level spatial planning. Two such examples are SDG indicator 11.3.1: ratio of land consumption to population growth rate (see: **Fig 5**) and SDG indicator 11.2.1: proportion of population that has convenient access to public transport (see: **Fig 6**). For the former, EO can provide timely measures of the physical boundary of cities (built up area) that can be combined with population growth data from other sources[9]. For the latter, EO can provide information on where residential areas are and their density, which can be combined with information on transit routes to measure access.

An intrinsic value proposition of EO is the standardized approach it takes for measurements. This means that using the same methodology leads to results in different areas that are comparable. Issues arising from inconsistencies of definitions between two or more locations or human error, as could be in the case with traditional approach to statistics, do not affect results from EO. For example, measurements of fine particulate matter (**Fig 4**) using EO gives comparable and standardized readings for the entire continent of Europe. This standardized approach can prove advantageous for decision makers that are looking for ways to take objective stock of a situation. For example, the identification and mapping of slums over large areas can easily be done using a combination of EO and machine learning at low-cost (see: **Fig 7**).

[8] Using the methodology from Bailey, J., Gerasopoulos, E., Athanasopoulou, E., & Speyer, O. (2019) Insight and Policy Implications from a Harmonized Earth Observation Approach to Urban Air Quality. eLighting Session at the AGU Fall Meeting 2019, San Francisco, California.

[9] For methodological details of calculating indicator 11.3.1 using EO, see: Schiavina et. al.(2019) Multi-Scale Estimation of Land Use Efficiency (SDG 11.3.1) across 25 Years Using Global Open and Free Data. Available at: https://bit.ly/2UAl0RN

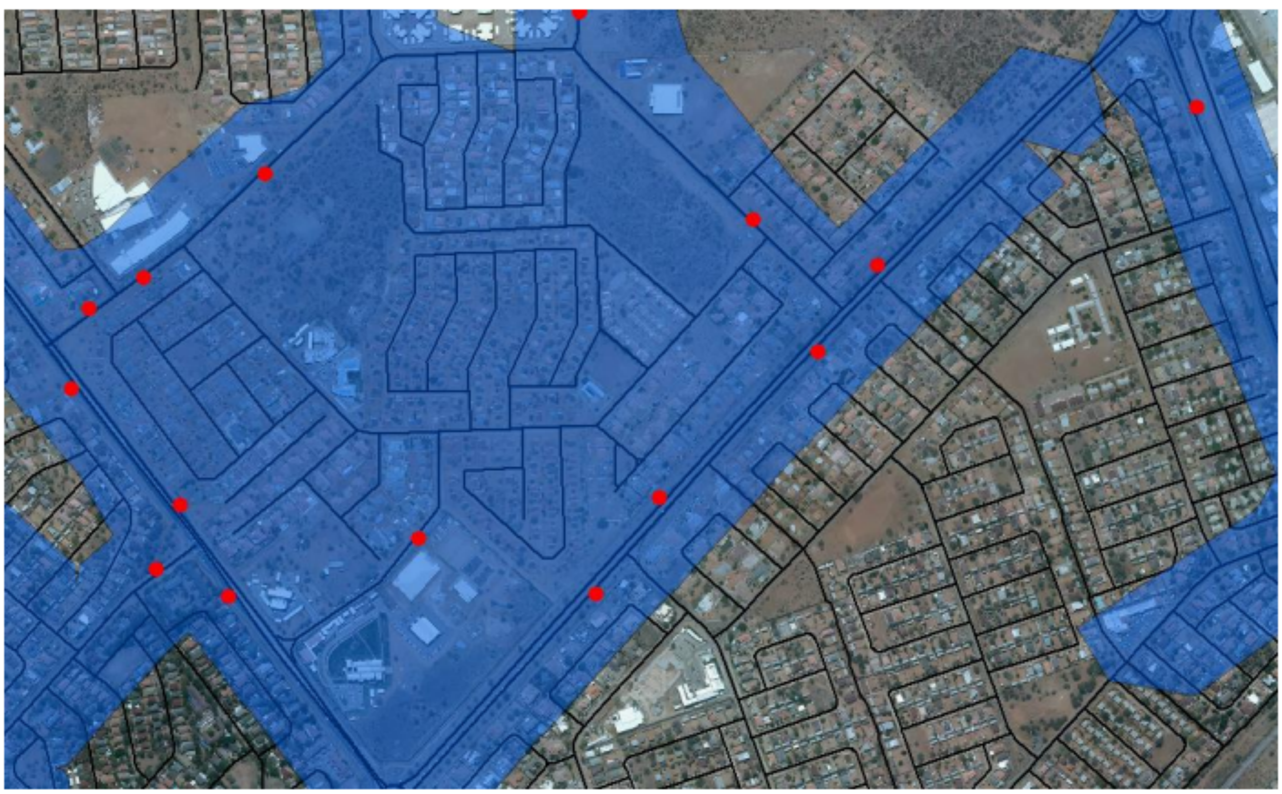
Fig 5: Measuring Land Consumption Rate



$$\mathrm{LCR} = \frac{\mathrm{LN}(\mathrm{Urb}_{t+n}/\mathrm{Urb}_{t})}{(y)}$$

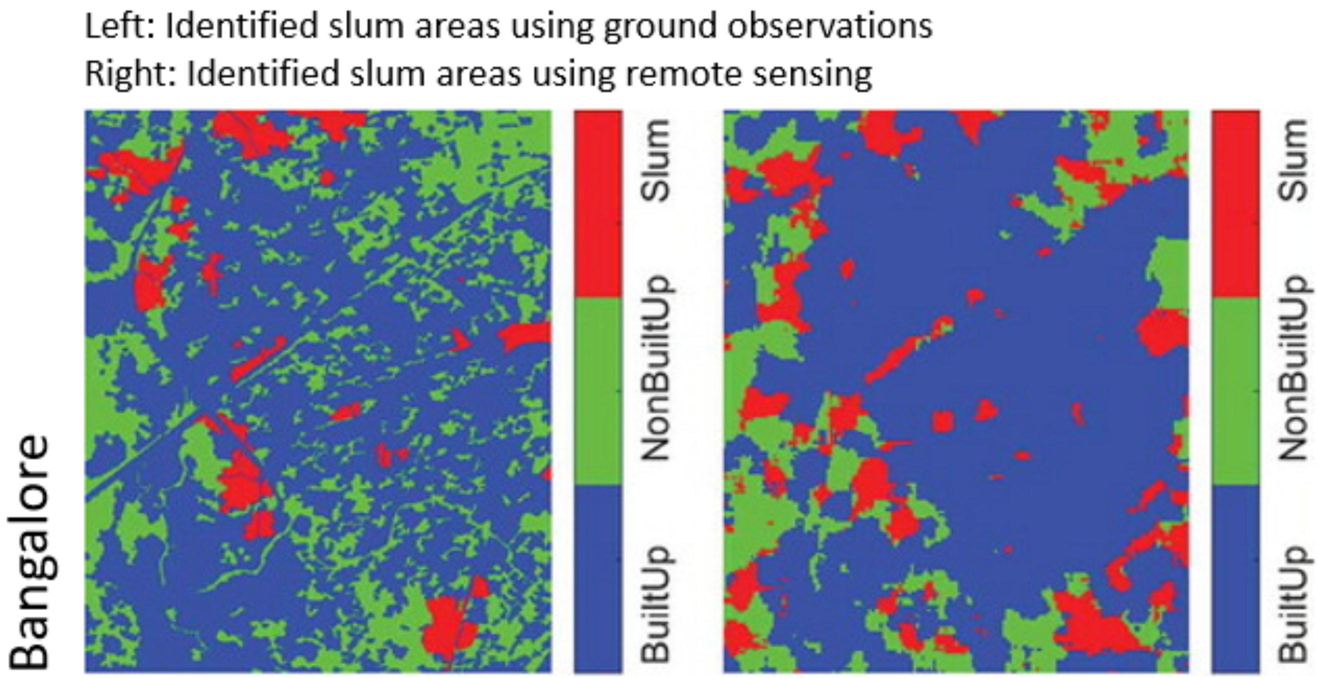
Source: Global Urban Observatory (GUO), UN-Habitat

Fig 6: Evaluating Access to Public Transport



Source: Global Urban Observatory (GUO), UN-Habitat

Fig 7: Identifying slum areas using remote sensing



Source: Ranguelova et. al. (2018)

Table 1: Applications of EO to various dimensions of global agendas

Urban Development Issues that can be Measured using Earth Observation	SDGs	NUA	Sendai Framework	Paris Agreement	Relevant Sources
Land Use					
Land consumption	11				Atlas of Urban Expansion, Trends.earth Urban Mapper
Public Space/Recreational Use/Open Spaces	11	✓			ESA Sentinel-2 MSI, MODIS Land Cover Maps
Length of Roads/Area Under Paved Roads	11	✓			Global Urban Observatory
Housing					
Population density	11	✓			Gridded population, GHSL
Population living in slums	11	✓			Global Urban Observatory, www.urban-tep.edu
Condition of dwelling (roof)	11	✓	✓		www.urban-tep.edu
Transportation					
Access to public transportation	11	✓			Global Urban Observatory
Water					
Soil moisture content	15, 6				NASA
Surface water detection	6	✓			ESA, MODIS, www.SDG661.app
Wetlands monitoring	15	✓			NASA
Precipitation	6, 11	✓			Univ. of Delaware
Air Quality					
PM 2.5/10	11, 3	✓			SMURBS
Air Temperature/Heat Islands		✓			Univ. of Delaware, EXTREMA project
Energy					
Energy access	11, 7	✓		✓	Night Time Lights (VIIRS, DMSP)
Climate Change					
Atmospheric Carbon concentration (emissions)	13	✓		✓	NASA JPL
Drought/Flood monitoring	11, 13	✓	✓		www.SDG661.app
Land surface temperature	11	✓	✓		MODIS (MOD11)
Other					
Gross domestic product	11, 8	✓	C1, D1	✓	Night Time Lights (VIIRS, DMSP)
Critical infrastructure			D1		Night Time Lights (VIIRS, DMSP)

Note: This table provides some example cases of issues related to urban development that can be monitored using EO. This list is not exhaustive and is shared for illustrative purposes only. Where possible, we have included specific goal or target. Check marks suggest relevance to the global framework but not an exact target/indicator match.
Source: Authors

Despite the low-cost nature of using open Earth observations, advances in EO and the opportunities it offers to the urban data ecosystem the EO community has been unable to trigger its large-scale adoption and use. This is often because of the technical capacity of local government offices and, possibly, the inertia against integrating EO data into everyday activities that changes the operational status quo.

III. Earth Observations: Overcoming Capacity Challenges in Cities[10]

Earth observation is a specialized science with a high entry barrier. Trained professionals with satellite image processing capabilities are limited in number, as compared to the need. Remote sensing jobs tend to be concentrated in specific institutions that specialize in remote sensing without contextual knowledge related to international development. The cohort of remote sensing specialists who work on urban studies is a further niche. Therefore, local government capacity to use remotely sensed data and Geographical Information Systems (GIS) software would need to be developed over the next decade to fully utilize the opportunities EO offers to cities with the ability to contextualize analyses to local needs.

Efforts are underway globally in advocating for governments at all levels to build such technological capabilities through strategic investments into human resource and computing infrastructure. Founded in 2005 at the 3rd Earth Observation Summit, the Group on Earth Observations (GEO) is an intergovernmental partnership that has been advocating for the use of openly available Earth observation data to tackle issues related to sustainable development. Working together with 109 Member Governments, GEO has made available over 400 million freely available EO data resources on the Global Earth Observation System of Systems (GGEOSS) portal. In addition, GEO is supporting national level policy makers to make use of EO data in their decision-making through the development of the GEO Knowledge Hub[11].

The Group on Earth Observations: Supporting sustainable cities with coordinated Earth observations

GEO coordinates a global work program of over 50 activities, using open EO, to address environmental and social challenges, many of which are keenly applicable to the challenges facing cities. Some of GEO's most notable initiatives of relevance to sustainable urban development are Global Urban Observation and Information (GUOI) initiative, the GEO Human Planet Initiative (HPI) and the Earth Observation in support of the Sustainable Development Goals (EO4SDG) initiative.

GEO's GUOI[12] is improving urban monitoring and assessment through international cooperation and collaboration to provide datasets, information, technologies to pertinent urban development professionals operating at the national and international level. Government agencies that typically use these EO datasets include departments of urban and regional planning, environmental management, natural resources, metropolitan transit authority, and office of sustainability, and regional statistics. GEO supports these agencies through technical assistance with accessing and developing robust datasets on urban land use/land cover, urban form and growth patterns, infrastructure and transport needs, ecosystems and biodiversity, human health, thermal comfort, food security, and socioeconomic development.

GEO's HPI provides services to international institutions and other stakeholders with next generation measurements and information products that provide new scientific evidence on humanity's impacts on the planet. A recent outcome of the HPI is the new 'Degree of Urbanization' dataset, which provides a universal and harmonized definition of cities based on population density and settlement size. This project was co-created by the European Commission, the Organization for Economic Cooperation and Development (OECD), Food and Agricultural Organization (FAO), UN-Habitat and the World Bank, and its outcomes under consideration for adoption in March 2020 by the UN Statistics Commission.

GEO's EO4SDGs program has engaged in efforts that support the development of tools and platforms that enable integration of EO into national data streams and decision support systems. One such example is the SDG661 application developed by UN Environment Programme (UNEP) in collaboration with Google and the European Commission's Joint Research Centre to track the quality of water ecosystems. EO4SDG is working with UNEP to identify more global EO datasets that can be incorporated in this application to expand the platform's tracking capabilities to other SDG indicators beyond 6.6.1

Besides these three work streams, other programs within GEO also have relevance to sustainable urban development. Few examples are: the Resilience Brokers initiative that works with stakeholders in the private sector to ensure that EO data is used effectively in disaster and emergency contexts; the SMURBS/ERA-PLANET H2020 project that promotes the "smart-city" concept through the integration of EO and other data at the urban level; the GEO Biodiversity Observation Network (GEOBON) that tracks key biodiversity indicators and the Earth Observation for City Biodiversity Index (EO4CBI) that extends this work to the city level; and GEO Wetlands that monitors wetland quality.

[10] This paper only discusses technical capacity as a limitation. In reality, technical capacity is one of several human barriers that often prevent the uptake of new technologies.

[11] GEO Knowledge Hub is an open-source digital library designed to serve the community and to ensure that all these components are visible, accessible, and that others can share their knowledge and experience in a codified manner for country-relevant, evidence-based decision-making in order to allow this knowledge to be reproduced. It will allow to advance reproducibility of the knowledge produced by the GEO community (Flagships, Initiatives and Community activities of the GEO Work Program).

[12] For more information on GEO's GUOI, see: https://bit.ly/2SeRQX7

Despite many successes through these programs and beyond, GEO still has much work to do on bringing more higher resolution, paid data into the open data, open access realm. Right now, most open source satellite images, such as those from Modis, Landsat and Sentinel satellites, are medium - low resolution images (10 meters and coarser). As technology improves and providers of high-resolution imagery lower their barriers through the efforts of global partnerships, such as GEO, the use of EO data in urban analytics would likely see an increase. For example, Maxar and Ecopia.ai are extracting every building and road throughout 51 countries in sub-Saharan Africa using very high-resolution satellite imagery and machine learning[13]. As governments and private stakeholders share more of their datasets, such as recent initiatives by China and Japan, data that are more granular will become available on the world's cities.

GeoQuery and Other Geospatial Tools: Making EO data accessible

While GEO and others work on building political will and developing geospatial capacity at the city level, AidData, a research lab at William & Mary, has been working on expanding the functionalities of its GeoQuery tool to the city level. GeoQuery is a public-good tool that allows users to start using data generated through EO by providing useful data in spreadsheet format. The goal of this web-based tool is to reduce the technical barriers associated with utilizing spatial data for policy planning and decision-making. GeoQuery is publicly available and powered by William & Mary's high-performance computing cluster, which automates the processing of terabytes of spatial data so that users are not limited by computational resources or technical skills. For example, users can request measures of air quality for their cities through an online form and receive an output emailed to them in spreadsheet format, which could then be visualized or analyzed on traditional spreadsheet software or mapped on GIS software, depending on the user's technical capability (see: **Fig 8**).

GeoQuery is not the only tool that eliminates the need for skills in remote sensing. Other similar tools also exist which provide information in forms that are usable by specific target audiences. For example: *PRIO Grid*, created by the Peace Research Institute Oslo, offers a range of data aggregated to a global grid; the *IPUMS Terra* offers information on population and environmental data; *Trends.Earth*[14] is a plugin for the open source desktop GIS software Quantum GIS that allows users to visualize land cover change over time; and *MapX* is an online platform that was developed by the UNEP which allows users to perform various GIS analyses and visualize data on natural resources. The overarching goal of these tools, and others like them, is to simplify working with geospatial data in varying contexts. However, GeoQuery is unique because it is not limited by its scope in terms of the datasets, boundaries, or applications for which is can be used[15]. Another strong value proposition of GeoQuery is that it provides data that is has been aggregated to administrative/political boundaries, which makes it more fit for local decision-making purposes.

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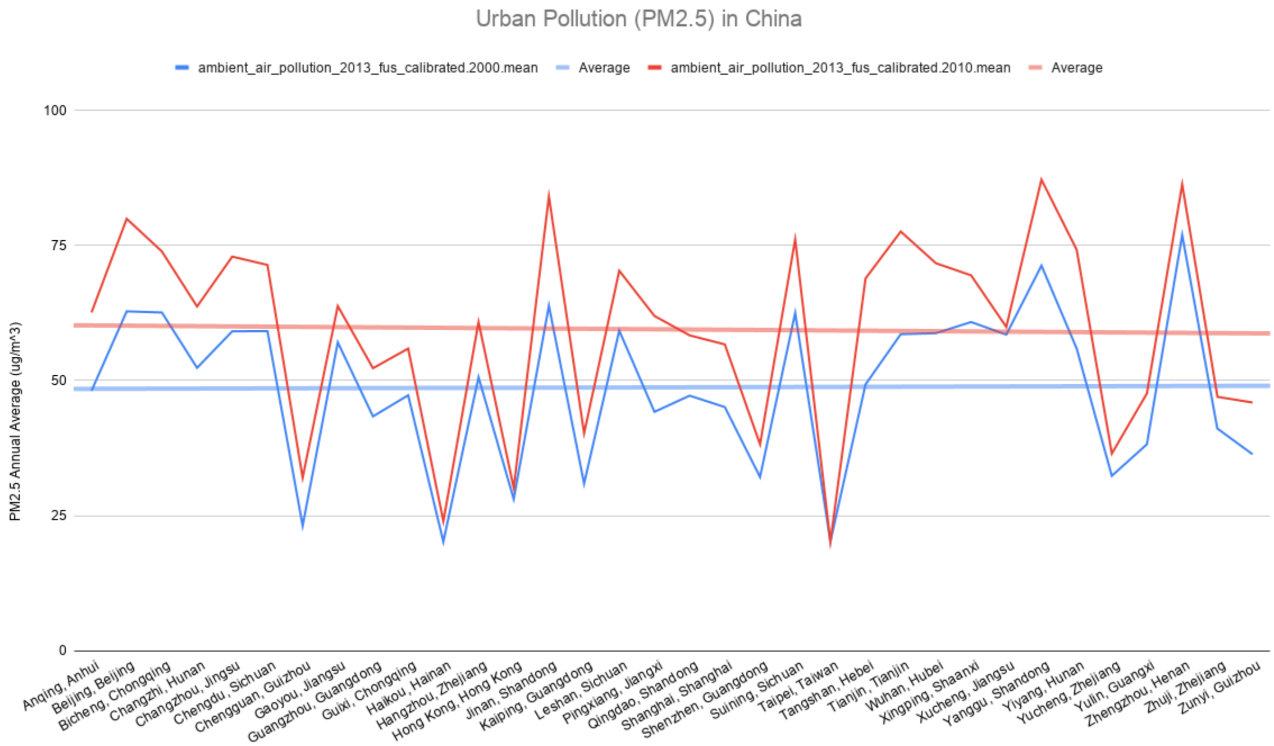
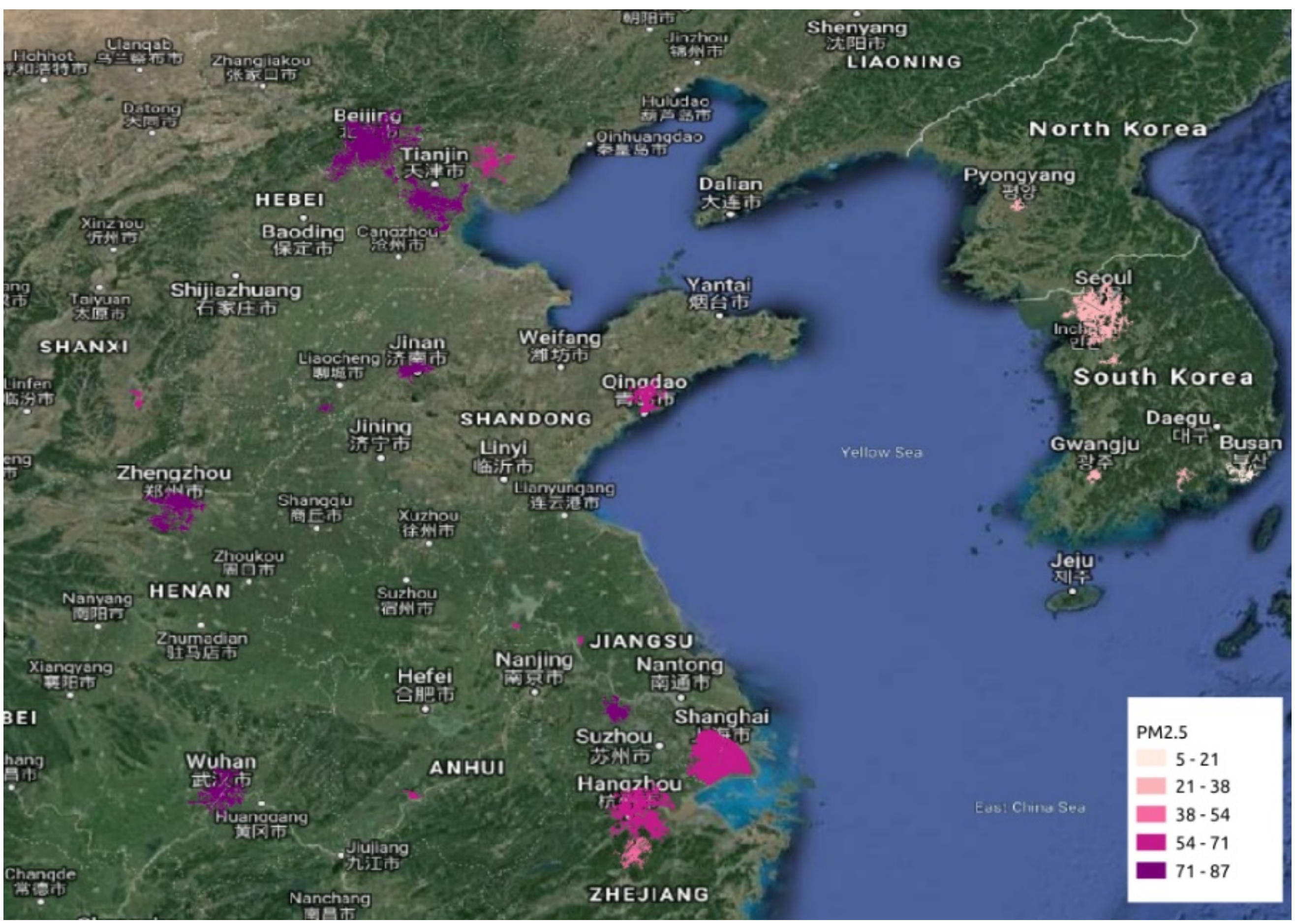
[13] For further information on this activity, see: Price, R. and M. Hallas (2019). Mapping Every Building and Road in sub-Saharan Africa. AGU 100 Fall Meeting, Dec. 9-13, 2019.

[14] Formerly called the Land Degradation Monitoring Toolbox, Trends. Earth was developed jointly by the Global Environmental Facility (GEF), Conservation International, Lund University and NASA.

[15] Being an open-source tool, GeoQuery is limited to sharing processed EO data that is freely available. This means that some information is older while others are recent. As newer datasets become freely available, GeoQuery will update its data offerings and temporal coverage accordingly.

Fig 8: GeoQuery Output on Air Quality in Chinese Cities graphed (top) and mapped (bottom) for 2000 and 2010.

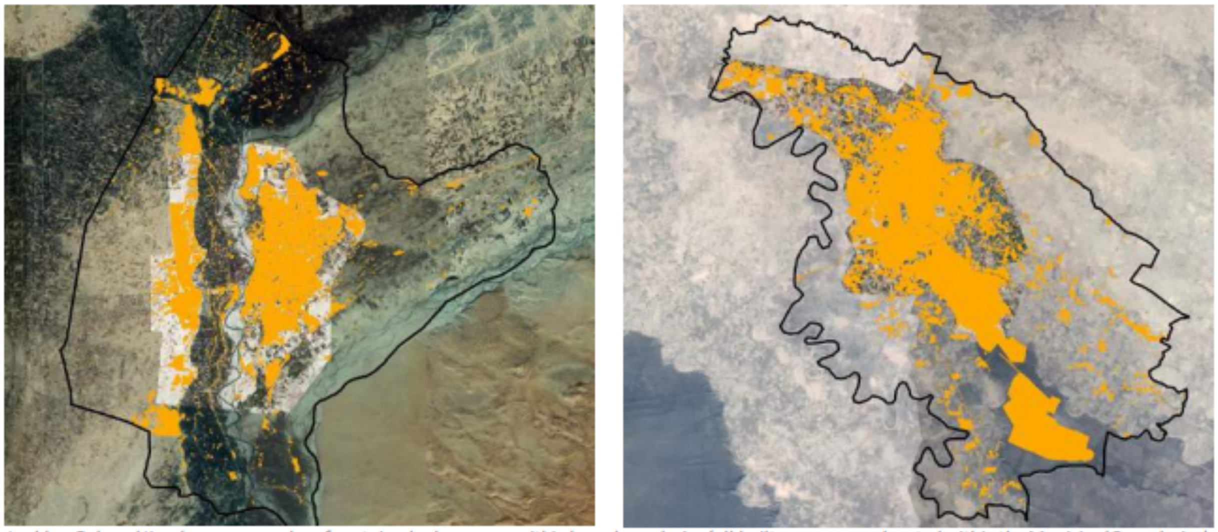




Source: GeoQuery, William & Mary

Nonetheless, any EO tool, including GeoQuery, can only generate data for those cities and other administrative units that have publicly available administrative/municipal boundaries. Many countries in the developing world are yet to create formal cadastral maps that delineate administrative boundaries of cities and other settlements, or even formally publish higher order administrative boundaries. In other cases, cities are not limited to their administrative boundaries. For instance, the greater Accra metropolitan area has twelve municipalities but the city of Accra is only one of the twelve. This is one of the drivers of urban research into universal definitions and delineations of cities (such as the Degree of Urbanization project discussed earlier), including definitions based on population densities and built-up areas, which can be very different from actual administrative jurisdictions that elected officials actually represent (see: **Fig 9**).

Fig 9: Municipal Boundaries versus Built Up Area Boundaries



Lashkar Gah and Kunduz are examples of contained urban areas within large boundaries (all built-up areas are located within the Municipal Boundaries).

Mazar-i-Sharif (above) and Ghazni (below) are examples of municipal boundaries that are too small because they do not accommodate all the built-up urban area. (Built-up areas within and outside the Municipal Boundary).

Note: Yellow denotes built-up areas and black lines represent municipal boundary. Source: Government of Afghanistan (2015) The State of Afghan Cities, Vol. 1

GeoQuery - What GeoQuery is and how can it support cities?

The core repository of data for GeoQuery combines a curated collection of over 60 disaggregated spatial datasets with hundreds of administrative and other boundaries worldwide. Users can browse this collection based on their desired area of interest, selecting boundaries which include administrative units as fine as administrative level 5 (ADM5) from GeoBoundaries, as well as a collection of 200 city boundaries from the Atlas of Urban Expansion. Based on the selected boundary and the time-period of interest, custom datasets are then created per the user's request and emailed for easy download and use.

Example datasets available through GeoQuery

Theme	Dataset	Source
Socio-economic	Nighttime lights (DMSP)	NOAA Earth Observation Group 2017
	Nighttime light (VIIRS)	Elvidge et al 2017
	Travel time to major cities	Nelson2008
	Population (Count and Density)	CIESIN 2000
	Conflict event counts	Raleigh et al 2010
	Conflict deaths	Sundberg and Melander 2013
International Aid	Chinese Finance	AidData 2019
	World Bank	World Bank, AidData 2017
	Global Environment Facility	GEF IEO, AidData 2017
	18 Country Specific Datasets	Various, AidData
Environmental / Geophysical	Land Cover	ESA 2009, MODIS 2013
	Elevation and Slope	NASA 2000
	NDVI	LTDR, NASA 2017
	PM2.5 and Ozone Concentration	Bouma et al 1997
	Air Temperature	Matsuura and Willmott 2015
	Precipitation	Matsuura and Willmott 2015
Other	Distance to Water	Wessel and Smith 1996
	Distance to Roads	CIESIN and ITOS 2013
	Distance to Country Borders	Hijmans 2015

Requested data takes the form of a simple spreadsheet (CSV file) in which each row represents an individual boundary feature (e.g., a city or a district) and each column represents the data selected (e.g., total population in 2000, total population in 2005 or average temperature in 2005). Providing users with data in CSV format allows users without experience working with spatial data, or the computational resources required to process large scale spatial datasets, to still gain the benefits and insights of incorporating subnational spatial data into the analysis and decision-making processes.

IV. Paving the way forward for Urban Earth Observations: Collaboration, Communication and Capacity Development

This paper highlighted some of the opportunities that EO offers to governments at all levels in overcoming evidence gaps, and shared various ongoing efforts that can be tapped into by city leaders as well as some of the tools that are available to improve their decision-making. The paper also suggested ways in which EO can be leveraged for tracking progress and reporting on global sustainable development agendas, which carry urban implications.

As the EO community continues to shift their focus from national level engagements to technical support for the data needs of urban leaders, a similar and matching move is required from cities in embracing geospatial technologies through: (i) active engagement with the EO community and communicating their needs; (ii) building strong collaborative frameworks; and (iii) investing in developing the necessary capacity within their city government agencies. Meanwhile, national governments need to also support cities in their pursuit of these three activities. Where necessary due to legal or administrative limitations, national or sub-national governments can also take lead in pursuing these three activities on behalf of urban settlements.

To facilitate increased collaboration in the EO sector, GEO invites countries and participating organizations to take part in the GEO Work Program. There are now over 50 activities approved with implementation plans for 2020-2022, and all are open to new membership. Collaborating with GEO under the HPI, EO4SDG or its other work streams will allow city governments and other urban stakeholder organizations to increase their collective impact, build on synergies and scale up best practices that are already working in cities across the globe.

Given the amount of programs already utilizing EO data, it is apparent that better data and information leads to better decision making. However, these benefits are not being effectively communicated to city leaders who are yet to capitalize on the offered opportunities. The EO community would need to improve its communication and advocacy efforts to create the necessary political will to enable this transition. Additionally, the EO community also needs to understand the nuances of local governance and government. City administration varies significantly within and among countries. Therefore, producing standardized data, based on grids or other popular techniques to generate information at scale, might be limiting its use to only higher order governments. AidData's GeoQuery tool has seen reasonable uptake[16] at lower levels of administration possibly because it provides data for administrative boundaries, and in highly accessible spreadsheet format. This may be a valuable insight for the EO community to act on to see higher uptake of EO data at the local level.

Lastly, part of this communication process between the EO community and the governments needs to be about the creation of realistic and actionable urban boundaries. Without these boundaries, there will be continued misalignment between the urban data that the EO community generates, using their own definitional criteria, and the data that city leaders would find actionable and the true measure of the status of development in their constituency.

[16] AidData has been tracking the demand for GeoQuery through the evaluation of its data requests.

Further Reading

UN Sustainable Development Solutions Network (2019). Counting on the World to Act. Available at: https://bit.ly/2H3PrIi

GEO (2017). Earth Observations in support of the 2030 Agenda for Sustainable Development. Available at: https://bit.ly/2S0ti3P

Goodman, S., BenYishay, A., Lv, Z., & Runfola, D. (2019). GeoQuery: Integrating HPC systems and public web-based geospatial data tools. *Computers & Geosciences*, *122*, 103-112.