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| **Indicator** | 11.3.1 Ratio of land consumption rate to population growth rate. | | |
| Target | 11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries. | | |
| Custodian | United Nations Human Settlements Programme (UN-Habitat). | Tier | II |
| Current approach and challenges | The indicator aims at monitoring and measuring urban development by comparing the urban expansion rate with the population growth rate on similar temporal and spatial scales. Indicator 11.3.1 measures how efficiently cities utilize land, which is measured as a ratio of the rate at which cities spatially consume land against the rate at which their populations grow.  The formula to derive the ratio of land consumption rate to population growth rate (LCRPGR) can be summarized as follows:   |  |  | | --- | --- | |  | [eq. 1] |   Practically, equation 1 is computed in a two-step process involving the data collection and estimation of population growth and land consumption respectively. The land consumption rate is defined as the uptake of land by urban developments including the urbanized open spaces. In essence the land consumption represent the change in urban extent over time and where urban extent is defined as the total built-up area of the city proper and the Urbanized Open Space in and around it, and where built-up area is the total area of the impervious surfaces in the city proper i.e. roofs, streets, and parking lots, but excluding urbanized open space, both public and private, as well as vacant lands, measured in hectares.  It is noted that the periods for both urban expansion and population growth rates should be at comparable scale. . The metadata for this indicator does not explicitly define the baseline year for the reporting periods rather it is anticipated that countries can report consistently after a few years and hereafter repeated regularly in 5-year intervals, allowing for three reporting points until the year 2030. In addition, and for better understanding how the consumption of land by cities contributes to sustainable urbanization – in line with target 11.3 - historical image analysis is highly encouraged for this indicator, with a proposed historical reference year of 2000.  The indicator has been classified as TIER-II meaning that the indicator is conceptually clear, and an established methodology exists but data on many countries is not yet available. The Global Human Settlement Layer (GHSL) technology open framework developed by the Joint Research Centre (JRC) and the European Commission (EC) is proposed for global open spatial baseline data production (built-up and population grids). The GHSL framework provides data and tools developed from EO, census data, and volunteered geographic information that produces global maps of built-up areas, resident population, and settlement typologies for four epochs (1975, 1990, 2000, and 2015). The GHSL global open data is available and will be updated through EU support and international partnership. The tools will be opened to national Authorities by a new platform and capacity building program.  Despite being classified as TIER II the reporting on 11.3.1 is still subject to a number of challenges including issues with the definition and estimation of respective the land consumption rate and the population growth rate. While the definition on land consumption is very specific the recommended data sources for its estimation is not in full accordance with the definition. By example, built-up area can be directly measured by EO technology, but it requires additional processing and a level of abstraction to convert or agglomerate the built-up area into urban extent. In addition, it may be difficult to measure the urban expansion of two or more urban areas in close proximity as it may be difficult to judge to which city the urban growth should be attributed.  Finally, and since most of the population lives in urban areas, it is often assumed that the residents in urban areas may be represented by the residents in administrative units containing such areas. But a recent UN-Habitat survey revealed the existence of major variations between what is statistically identified as urban (the separation of enumeration areas into urban and rural as implemented by national statistical offices, for census purposes), and what is officially defined or mapped as urban (as per existing municipal or city boundaries in the country). | | |
| **Opportunities for Earth Observation** | | | |
| Opportunities for EO | Earth Observation is recognized as an important data source for measuring this indicator. EO has direct relevance for mapping and monitoring changes in the built-up area and for defining the extent of urban area but EO are also indirectly supportive for generating disaggregated maps of global, regional or national census data.  **Built-up area**: Earth Observation data is well equipped for mapping built-up areas and as of today several global datasets are available including the Global Human Settlement Built-up (GHS BU) developed by JRC/EC and the Global Urban Footprint (GUF) developed by DLR. Although impressive in term of high spatial resolution and global coverage, these datasets come with certain caveats. By example the GHS BU relies solely on Landsat data and with reported issues related to confusion of bare soil and urban areas. Contrary the GUF relies solely on radar imagery and the public can only access an aggregated version of the GUF product (i.e. 75 meters vs. the full resolution in 12 meters) and only for the year 2012. The new World Settlement Footprint 2015 (WSF-2015) developed by DLR/ESA is addressing some of the issues with GHS BU and GUF by using Landsat 8 and Sentinel 1 radar imagery to provide a global overview of the world’s human settlements in 10-meter resolution. Currently, WSF 2015 is only available for online visualization on the Urban TEP. It should be mentioned that ESA and DLR has initiated WSF 2018 an update and evolution of WSF 2015 based on the joint use of Sentinel 1 and Sentinel 2 imagery. The WSF 2018 will be freely and openly available by end of 2019. The WSF evolution (done by DLR in partnership with Google Earth Engine) should also be mentioned as it will use Landsat imagery to provide detailed information about the spatiotemporal development for each human settlement identified in the WSF 2015, over the last 30 years.  An alternative and user driven solution for mapping built-up areas is Trends.Earth Urban Mapper which is an online interactive platform developed by Conservation International (CI) in partnership with NASA, for mapping built-up and non-built up impervious areas from archived Landsat imagery (i.e. from 2000 to 2015). For more information on the global datasets and platforms please refer to next section.  By using global datasets users will be restricted e.g. in terms of definitions, available reference years and the spatial resolution. By example, the definition of built-up area adopted by GHS BU, GUF and WSF only consider the extent of buildings i.e. impervious areas with vertical dimension and hence excluding streets and parking lots which is part of the urban extent definition under SDG 11.3.1. While Trends.Earth Urban Mapper is better aligned in terms of the built-up area definition then the approach is restricted Landsat imagery which has an inferior spatial resolution compared to Sentinel imagery.  These issues can be addressed and controlled by countries if they invest their own resources in the mapping of built up areas. By example, countries such as Mexico and Colombia are already developing Geospatial Data Cubes to enable processing and analysis of satellite images for mapping built-up areas as well as other critical land surface indicators.  Today, the most realistic and feasible option for national built-up area mapping is to use the freely available datasets provided by the European Sentinel-1 (SAR) and Sentinel-2 (multispectral) as well as the US Landsat (multispectral) missions. These open datasets provide systematic multi-sensor acquisitions in 10-30 meter resolution with a huge potential for advancing the mapping of built-up areas. The full potential of the Sentinels to improve built-up area mapping is yet to be realized into public domain products, but open source tools such as SNAP, QGIS, and Massive Spatial Automatic Data Analytics can all support the mapping of built-up areas from Earth Observation. Users should be aware that significant computing and data storage resources are required when working at national scale with annual or longer timeseries of Sentinel-1 and Sentinel-2 data. Therefore, linkages to existing and well-established data infrastructures or Cloud Platforms with co-located satellite datasets (e.g. Google Earth Engine, DIAS etc.) need to be considered, and it is recommended that countries who want to pursue their own mapping should evaluate the requirement for assistance from a national entity/GIS unit or assistance from a specialized service provider.  It is also worth mentioning that commercial satellite imagery with sub-meter spatial resolution offer an opportunity to map the built-up area in higher detail compared to the free and open datasets. For national scale mapping the use of commercial high-resolution imagery will most likely be prohibitive costly for most countries but may be considered in a multi-scale approach where the national built-up inventory is based on public domain data or from open datasets which is being complemented with detailed built-up inventories for selected cities based commercial high-resolution imagery.  Regardless of the input satellite imagery then users should be aware that the direct output of the EO processing is a map of the built-up area why post-processing is needed in order to derive the urban extent boundary and the degree of land consumption which is needed for this indicator.  **Population mapping:** It is not possible to directly estimate population numbers or density from space but there are established methodologies for generating population maps by obtaining sub‐national population statistics (e.g. districts, counties, provinces) and subsequently distribute them geographically using geospatial indicators such as the location of urban centres (cf. Urban extent) and possibly also the main transportation network, i.e. roads, railroads and rivers. By knowing the type and use of the urban fabric then coarse resolution population maps can be disaggregated to obtain a more accurate spatial assignment of the population density. | | |
| EO datasets and platforms | There are a range of satellite data sources and global data products which could be used within the indicator reporting. In addition, there are several online platform and tools who provide options and support for accessing or deriving various inputs for computation of indicator 11.3.1.  **Satellite data**  Raw satellite imagery for the mapping of built-up areas can be obtained from public and freely-accessible data collections as well as from commercial distributors. A summary of the available options is provided in the table below:   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Sensor | Type | Spatial resolution | Temporal coverage / Revisit time | Data policy | Comment | | Sentinel-1 | SAR | 10 m | From 2014 /  At least every 12 days globally | Free and open | Limited historical data but the long-term continuity is secured under the Copernicus program | | Seninel-2 | Multi-spectral | 10 m | From 2015 /  Every 5 days globally | Free and open | Limited historical data but the long-term continuity is secured under the Copernicus program Sensitive to clouds why useful imagery may be restricted in cloudy regions | | Landsat | Multi-spectral | 30 m | Since 1984 /  Every 16 days globally | Free and open | The 30-meter resolution is a drawback compared to the Sentinels, but the long temporal coverage is invaluable for historic mapping. Sensitive to clouds (useful imagery may be restricted in cloudy regions). | | Commercial | SAR and Multi-spectral | 0,5 to 2.5 meters | Since ~2000;  New acquisitions (on demand); Historic imagery (depending on archive) | Proprietary / Cost from 2.5 to 20 €/km2 | Provides the highest level of detail but at expense of cost |   Sentinel data can be accessed through the Data and Information Access Services (DIAS) or the Conventional Data Hubs (<https://www.copernicus.eu/en/access-data>) while Landsat data is available via the EarthExplorer (<https://earthexplorer.usgs.gov/> ). Commercial satellite data can be purchased through data providers and their reseller network.  **EO based global datasets**  *Built-up datasets*:   * **The Global Human Settlement Built-up** (GHS BU) is developed and maintained by the European Commission’s Joint Research Centre (JRC). It relies on several Landsat image collections to automatically retrieve information about settlement extent for selected time epochs i.e. 1975, 1990, 2000 and 2015: <https://ghsl.jrc.ec.europa.eu/data.php> * **The Global Urban Footprint** (GUF) developed by the German Aerospace Center (DLR), based on 2010–2014 X-band SAR (Synthetic Aperture Radar) imagery acquired by TerraSAR-X and TanDEM—X. It shows urban, non-urban and water areas globally at resolutions up to 12 m (75 meters for public access). (<https://www.dlr.de/eoc/en/desktopdefault.aspx/tabid-9628/16557_read-40454/>) * The **World Settlement Footprint 2015 (WSF-2015)** is the first map, using mass collections of Landsat and Sentinel-1 imagery from 2014-15 timeframe, to provide a global overview of the world’s human settlements. WSF has been developed by DLR under ESA funds and currently available for viewing on U-TEP: <https://urban-tep.eu/puma/tool/?id=574795484&lang=en>. An updated version (i.e. WSF-2018) based on Sentinel-1 and sentinel-2 imagery will be available by end of 2019. In preparation is also the WSF evolution product which relies on Landsat Imagery to map historical changes relative to WSF 2015. * The **Atlas of Urban Expansion** is an open-source online resource with maps, satellite images, and data on spatial changes in cities around the world from 1990 to 2015. The atlas is created in partnership by the Lincoln Institute of Land Policy, UN-Habitat, and New York University (<http://www.atlasofurbanexpansion.org/> ) * **High Resolution Settlement Layer (built-up area)**: A high-resolution settlement extent datasets developed by the Connectivity Lab at Facebook using computer vision techniques to classify blocks of optical satellite data as settled (containing buildings) or not. The settlement layer has been developed for 33 countries: <https://www.ciesin.columbia.edu/data/hrsl/>   *Population datasets:*   * **Global Human Settlement population** (GHS-POP): it uses the GHS-BU layer to make a spatial prediction of population census data: <https://ghsl.jrc.ec.europa.eu/data.php> * **WorldPop**: open access archive of spatial demographic datasets for Central and South America, Africa and Asia: <http://www.worldpop.org.uk/> * **Gridded Population of the world**: The Gridded Population of the World (GPW) models the distribution of human population (counts and densities) on a continuous global raster surface (~1 km resolution). GPW is developed and maintained by CIESIN: <https://sedac.ciesin.columbia.edu/data/collection/gpw-v4> * **High Resolution Settlement Layer (population estimate)**: Estimates of human population distribution (number of persons and extent of settlements) at a resolution of 1 arc-second (approximately 30m) for the year 2015. The population estimates are based on recent census data and the high-resolution settlement extent developed by the Connectivity Lab at Facebook (cf. High Resolution Settlement Layer (built-up area)). CIESIN used proportional allocation to distribute population data from subnational census data to the settlement extents. The population data have been developed for 33 countries. <https://www.ciesin.columbia.edu/data/hrsl/>   While the above datasets represent important disaggregated (using EO) global population datasets then it is worth the mentioning that the UNSD metadata for indicator 11.3.1. also makes reference to UN DESA population data <http://www.un.org/en/development/desa/population/publications/database/index.shtml> as the reference dataset for SDG 11.3.1. It is equally important to mention the fact that census data should be readily available from National Statistical Offices (NSOs), although the level of disaggregation may vary from country to country. In this regard it is worth mentioning that EO can provide support for disaggregating population data.  **Platform and tools***:*   * **Global Human Settlement Layer (GHSL)** is a framework that provide new spatial data mining technologies for the automatic processing, analytics and knowledge extraction from large amount of heterogeneous spatial data. Amongst others these tools provide users with options to map built-up areas from remote sensing data as well as estimating the land use efficiency from the GHSL and in support of measuring SDG 11.3.1: <https://ghsl.jrc.ec.europa.eu/tools.php> * **Trends.Earth** is an online platform from Conservation International (CI) and NASA for monitoring land change using earth observations in an innovative desktop and cloud-based system. Amongst others, Trends.Earth Urban Mapper allow users to produce built-up area maps at selected time steps using a combination of various Landsat imagery on Google Earth Engine (cf. <https://geflanddegradation.users.earthengine.app/view/trendsearth-urban-mapper> * The **Urban Thematic Exploitation Platform** (U-TEP) presents a web-based platform that allows users to effectively utilize Earth Observation (EO) imagery and existing auxiliary data (e.g., geo-data, statistics) to measure and assess key properties of the urban environment and monitor the past and future spatiotemporal development of settlements. In particular it is worth mentioning that U-TEP offers dedicated tool for SDG 11.3.1 monitoring and reporting based on the WSF global datasets: <https://urban-tep.eu/puma/tool/> * The **POPGRID** Data Collaborative aims to bring together and expand the international community of data providers, users, and sponsors concerned with georeferenced data on population, human settlements and infrastructure. Such data can help improve access to public and private services, increase the sustainability of natural resources, and facilitate progress towards meeting the internationally accepted Sustainable Development Goals (SDGs): <https://www.popgrid.org/home> | | |
| International Initiatives | **GEO Human Planet Initiative (HPI)** is committed to developing a new generation of measurements and information products that provide novel evidence-based assessment of the human presence on the planet Earth. The Human Planet leverages on advances of Earth Observation technologies and geo-spatial data analytics for improving the global awareness on the spatial patterns and processes of the today’s urbanizing world. The GHI core partners include Joint Research Center (JRC), Global Human Settlement Layer project (GHSL), the University of Southampton WorldPop project, and the Columbia University, Center for International Earth Science Information Network (CIESIN) but all together more than 150 individual scientists and policy makers belonging to 85 different organizations are involved: <https://www.earthobservations.org/activity.php?id=119>  **GEO Global Urban Observation and Information (GUOI)** intends to improve urban monitoring and assessment through international cooperation and collaboration, to provide datasets, information, technologies to pertinent urban users (World Bank, UN, and planning and environmental management agencies, especially in developing countries), and to support UN SDG Goal 11: Make cities inclusive, safe, resilient and sustainable. This Initiative will generate various data products of global urban areas using Earth Observation (EO) data, provide EO-based urban data services through various systems and tools, develop new models and algorithms to detect, assess, monitor, and model urban areas and environments, create new knowledge to fill the gaps in the integration of EO and other datasets for a better understanding of cities and develop essential urban variables and indicators for sustainable cities: <https://www.earthobservations.org/activity.php?id=125> | | |
| **Proposed Methodology** | | | |
| Step-by-Step guide for EO integration into SDG indicator framework | The Metadata on SDGs Indicator 11.3.1 (version: March 2018) outlines in detail the current method of computation including a section on data sources and collection. The latter explicitly referring satellite data as a key information source to be incorporated into the reporting framework: <https://unhabitat.org/wp-content/uploads/2019/04/Metadata-on-SDG-Indicator-11.3.1.pdf>  The Monitoring and Reporting guideline for Land consumption (Jan 2019) provides a step by step introductory to the estimation of indicator 13.3.1 including an example of using visual interpretation of satellite imagery to measure urban change, and how to use geospatial analytics to estimate the urban extent from the built-up area : <https://unhabitat.org/wp-content/uploads/2019/02/Indicator-11.3.1-Training-Module_Land-Consumption_Jan-2019.pdf>  While the Metadata and reporting guidelines is quite explicit about the integration of EO into the indicator computation they are less elaborate about the decision and implementation process that is an integral part of applying Earth Observation data and products. Some of the key question that needs to be considered before integrating EO into the indicator reporting are: Does the freely available products meet requirements in terms of spatial resolution, frequency, continuity, period of interest and accuracy? Is in-house capability available and adequate? Is training needed? Are local and international resources required?  The relevance of these questions is exemplified below in the outline of the basic steps that needs to be followed by users who wish to integrate EO for estimation of indicator 11.3.1.  **STEP 1: Get data**  As a first step users need to verify whether the public domain datasets are representative of the reporting period as well as consider the need and availability of more precise datasets. If the public domain datasets are considered inadequate users have the option to acquire new EO imagery and census data to generate updated information on urban extent and population density. Typically, census data will be obtained through the NSO while users who wish to acquire new EO imagery to generate updated information on urban extent can chose between openly available imagery (e.g. Sentinel and Landsat) and commercial high-resolution imagery – or a combination of both.  **STEP 2: Process data**  Although built-up and/or impervious surface mapping is an established field within Earth Observation applications then no standardized classification approach has been developed and approaches tend to vary according to the sensors used and the objectives and scale of study. In most cases, however, the acquired input data is subject to standard pre-processing routines for orthorectification, atmospheric correction and, if relevant, topographic normalization. The mapping itself is typically done using either pixel or object-based image classification based on multi-sensor EO data (e.g. Sentinel-1 and -2) and using spectral, textural and/or contextual features to classify the extent of the built-up and non-built up impervious areas. It is recommended that outputs are subject to manual post-processing for refinement and quality control.  Additional processing is also needed to convert the built-up area into a map of the urban extent which apart from the built-up area also includes the urbanized open space. This process of urban agglomeration can be implemented using simple visual interpretation or automatic geospatial techniques both techniques are illustrated in Monitoring and Reporting guideline for this indicator (<https://unhabitat.org/wp-content/uploads/2019/02/Indicator-11.3.1-Training-Module_Land-Consumption_Jan-2019.pdf>).  The thematic accuracy can be expected to be around 90% but deviation can occur depending on the character of the urban landscape. For this indicator, it is recommended to consider analysis periods with intervals of 5 or more years. Based on pilots undertaken by UN-Habitat, shorter time intervals do not produce significantly different results, unless such analysis is undertaken using high resolution (and often costly) satellite imagery. It is recommended but not required to explore the Landsat archive for historic analysis to better understand urban growth trends and how these affects sustainable development.  Once the urban extent has been defined users need to estimate how many people live within those areas. In the absence of high-resolution population data from the NSO users need to rely om gridded population data. As gridded population data normally comes in a much coarser scale than the urban extent map users should resample the population grids using the urban extent map as the weighting factor so non-urban areas will have less weight than the urban areas.  **STEP 3: Validate the results**  Validation is defined as the process of establishing documented evidence to provide a high degree of assurance that a specific process will consistently generate a product meeting its predetermined specification and quality attributes. Validation is important for any application of Earth Observation as it establish the expected accuracy and uncertainties of a derived product and hence its credibility for an intended usage.  Validation should be according to best practice which dictate adhering to a set of fundamental requirements, including: **Independence**, i.e. only using data and experts which have not been part of production; **Timeliness**, i.e. only using reference data which are timely and frequent enough to evaluate the accuracy of a given product; and **Validity**, i.e. always using reference data with a higher quality than those used for production.  As the number of pixels and/or objects in Earth Observation maps are too large to all be surveyed the most popular data validation methods relies on sampling. The sampling needs to be carefully designed to ensure statistical validity, and yet still accommodating practical realities in terms of cost and time constraints. Various probability sampling designs are suitable to assess the accuracy of maps, the most commonly used are based on simple random, stratified random, and systematic selection of sampling units. No single sampling design can serve as a universally appropriate design; however, stratified random sampling is a practical and cost-efficient design that satisfies the basic accuracy assessment objectives and most of the desirable design criteria. Stratified random sampling affords the option to increase the sample size in classes and/or regions that occupy a small proportion of area to reduce the standard errors of the class/region-specific accuracy estimates for these rare occurrences. A further advantage of stratified random sampling is also the ability to augment a sample when new data or updates become available without compromising the statistical rigor.  Independent, timely and valid sample data is typically gathered in field and/or from higher resolution imagery acquired by satellite, flight or drone borne sensors. In all cases the urban vs. non-urban margin can easily be interpreted and it is the general expectation that the validation of built-up areas and the derived urban extent maps against such reference data should return a classification accuracy in the order of 90%. | | |
| **Recommendations for implementation** | | | |
| Activities | *Tentative, not necessarily in sequential order*   * Evaluate the usefulness of global public domain datasets and tools for national reporting. This could be done for a few selected countries where SDG 11.3.1 have already been estimated with high resolution good quality input layers which can act as reference; * Implement a few country studies where SDG 11.3.1 is estimated by taken full advantage of the Sentinel imagery for temporal mapping of built-up and non-built-up impervious areas for estimation of urban extent and their integration with national census from the NSO’s to get the ratio of land consumption rate to population growth rate; * Run processing tests and prepare a design document that details the computing and data storage requirements for countries who wish to take advantage of timeseries of Sentinel-1 and Sentinel-2 data for SDG 11.3.1 estimation and reporting. The design document should also detail how similar resources could be requested though well-established data infrastructures or Cloud Platforms. | | |
| Timeframe | **Current indicator timeframe considerations:**   * According to the latest metadata It is anticipated that countries can report consistently after 2-3 years (relative to 2018) and hereafter repeated regularly in 5-year intervals, allowing for three reporting points until the year 2030.   **Tentative timeframe considerations for ESA initiative:**   * Technology is mature and EO services already established and ready to be demonstrated. | | |
| **References** | **Indicator background**   * Indicator 11.3.1 Metadata (March 2018): <https://unhabitat.org/wp-content/uploads/2019/04/Metadata-on-SDG-Indicator-11.3.1.pdf> * Indicator 11.3.1 Training Module: Land Consumption (Jan 2019): : <https://unhabitat.org/wp-content/uploads/2019/02/Indicator-11.3.1-Training-Module_Land-Consumption_Jan-2019.pdf> * Indicators and a Monitoring Framework: Launching a data revolution for the Sustainable Development Goals: <http://indicators.report/indicators/i-68/> * 2016 Atlas of urban expansion report <https://www.lincolninst.edu/sites/default/files/pubfiles/atlas-of-urban-expansion-2016-volume-1-full.pdf>   **Publications**   * Corbane, C., Politis, P., Siragusa, A., Kemper, T. and Pesaresi, M., LUE User Guide: A tool to calculate the Land Use Efficiency and the SDG 11.3 indicator with the Global Human Settlement Layer, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-73631-5 (print); 978-92-79- 73630-8 (pdf), doi:10.2760/16919 (print), 10.2760/212689 (pdf), JRC108026 * Esch, T., Bachofer, F., Heldens, W., Hirner, A., Marconcini, M., Palacios-Lopez, D., ... & Gorelick, N. (2018). Where we live—A summary of the achievements and planned evolution of the global urban footprint. Remote Sensing, 10(6), 895. * Pesaresi et al. 2016. Atlas of the Human Planet - Mapping Human Presence on Earth with the Global Human Settlement Layer <https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/atlas-human-planet-mapping-human-presence-earth-global-human-settlement-layer>   **EO technical sites**  Atlas of Urban Expansion: <http://www.atlasofurbanexpansion.org/>  Data and Information Access Services: <https://www.copernicus.eu/en/access-data/dias>  Earth Explorer: <https://earthexplorer.usgs.gov/>  Global Human Settlement Built-up (GHS BU): <https://ghsl.jrc.ec.europa.eu/data.php>  Global Human Settlement population (GHS-POP): <https://ghsl.jrc.ec.europa.eu/data.php>  Global Human Settlement Layer (GHSL): <https://ghsl.jrc.ec.europa.eu/tools.php>  Global Urban Footprint (GUF): <https://www.dlr.de/eoc/en/desktopdefault.aspx/tabid-9628/16557_read-40454/>  Gridded Population of the world: <https://sedac.ciesin.columbia.edu/data/collection/gpw-v4>  High Resolution Settlement Layer: <https://www.ciesin.columbia.edu/data/hrsl/>  POPGRID: <https://www.popgrid.org/home>  The Urban Thematic Exploitation Platform (U-TEP): <https://urban-tep.eu/puma/tool/>  Trends.Earth Urban Mapper: cf. <https://geflanddegradation.users.earthengine.app/view/trendsearth-urban-mapper>  WorldPop: <http://www.worldpop.org.uk/>  World Settlement Footprint 2015 (WSF-2015): <https://urban-tep.eu/puma/tool/?id=574795484&lang=en>  UN DESA population data: <http://www.un.org/en/development/desa/population/publications/database/index.shtml> | | |