JRC TECHNICAL REPORT

GHSL Data Package 2019

Public release
GHS P2019

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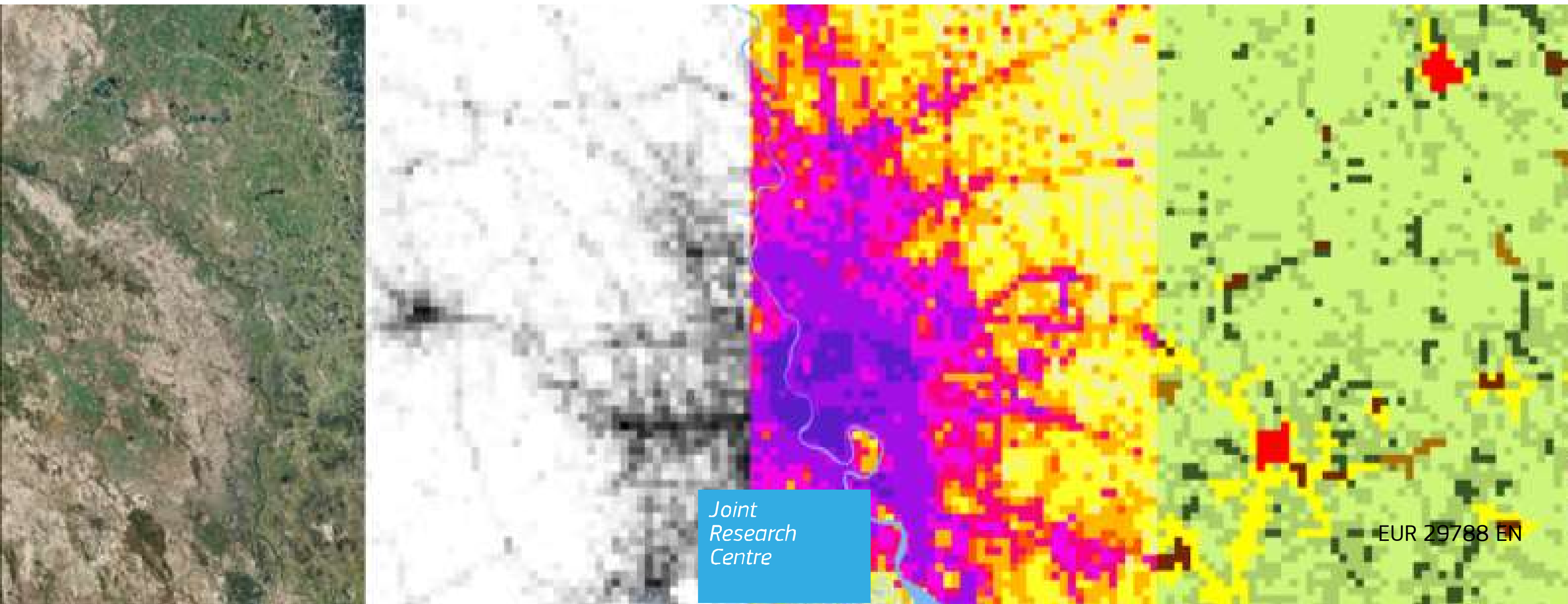
2019



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Abstract

The Global Human Settlement Layer (GHSL) produces new global spatial information, evidence-based analytics and knowledge describing the human presence on the planet Earth. The GHSL operates in a fully open and free data and methods access policy, building the knowledge supporting the definition, the public discussion and the implementation of European policies and the international frameworks such as the 2030 Development Agenda and the related thematic agreements. The GHSL supports the GEO Human Planet Initiative (HPI) that is committed to developing a new generation of measurements and information products providing new scientific evidence and a comprehensive understanding of the human presence on the planet and that can support global policy processes with agreed, actionable and goal-driven metrics. The Human Planet Initiative relies on a core set of partners committed in coordinating the production of the global settlement spatial baseline data. One of the core partners is the European Commission, Directorate General Joint Research Centre, Global Human Settlement Layer project. The Global Human Settlement Layer project produces global spatial information, evidence-based analytics, and knowledge describing the human presence on the planet.

This document describes the public release of the GHSL Data Package 2019 (GHS P2019). The release provides improved built-up area and population products as well as a new settlement model and functional urban areas

Prior to cite this report, please access the updated version available at:
http://ghsl.jrc.ec.europa.eu/documents/GHSL_Data_Package_2019.pdf

1 Introduction

1.1 Overview

The Global Human Settlement Layer (GHSL) project produces global spatial information, evidence-based analytics, and knowledge describing the human presence in the planet. The GHSL relies on the design and implementation of new spatial data mining technologies that allow automatic processing, data analytics and knowledge extraction from large amounts of heterogeneous data including global, fine-scale satellite image data streams, census data, and crowd sourced or volunteered geographic information sources.

This document accompanies the public release of the GHSL Data Package 2019 (GHS P2019) and describes the contents.

- Each product is named according to the following convention:

GHS_<name>_<temporalCoverage>_<spatialExtent>_<releaseId>

For example, a product name “GHS_BUILT_LDSMT_GLOBE_R2018A” indicates the GHSL Built-up area layer (GHS-BUILT) with multi-temporal coverage and a global spatial extent release R2019A.

- Each dataset is named according to the following convention:

GHS_<name>_<epochCode>_<extent>_<releaseId>_<EPSG>_<resolution>_<version>.<ext>

A dataset unique identifier like “GHS_POP_E2000_GLOBE_R2019A_54009_250_V1_0.tif” indicates the GHSL Population layer (GHS-POP) of the epoch 2000 with global extent, release R2019A in World Mollweide projection at 250 m resolution v1.0 in GeoTiff format.

The GHSL Data Package 2019 contains the following products:

- GHS Built-up area grid (GHS-BUILT), derived from Sentinel-1 (2016), R2018A [GHS_BUILT_S1NODSM_GLOBE_R2018A]. This product was distributed as part of the Community pre-Release of the GHSL Data Package 2018 (GHS CR2018) (Florczyk *et al*. 2018);
- GHS Built-up area grid (GHS-BUILT), derived from Landsat, multi-temporal (1975-1990-2000-2014), R2018A [GHS_BUILT_LDSMT_GLOBE_R2018A];
- GHS population grid (GHS-POP), derived from GPW4.1, multi-temporal (1975-1990-2000-2015), R2019A [GHS_POP_MT_GLOBE_R2019A]. This product was distributed as part of the Community pre-Release of the GHSL Data Package 2018 (GHS CR2018) (Florczyk *et al*. 2018); however, an updated version of the datasets is available (v2.0);
- GHS Settlement Model grid (GHS-SMOD), derived from GHS-POP and GHS-BUILT, multi-temporal (1975-1990-2000-2015), R2019A [GHS_SMOD_POPMT_GLOBE_R2019A].
- GHS Degree of Urbanisation Classification (GHS-DUC), derived from GHS-POP, GHS-BUILT, GHS-SMOD multi-temporal (1975-1990-2000-2015), R2019A and GAMD3.6[1] [GHS_STAT_DUCMT_GLOBE_R2019A].

1.2 Rationale

Open data and free access are core of principles GHSL (Melchiorri et al., 2019). They are in-line with the Directive on the re-use of public sector information (Directive 2003/98/EC[2]). The free and open access policy facilitates the information sharing and collective knowledge building, thus contributing to a democratisation of the information production.

The GHSL Data Package 2019 contains the new GHSL data produced at the European Commission Directorate General Joint Research Centre in the Directorate for Space, Security and Migration in the Disaster Risk Management Unit (E.1) in the period 2017 – 2019.

[1] https://gadm.org/index.html
[2] http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32003L0098

1.3 History and Versioning

In 2016 the first GHSL Data Package was released (GHS P2016). It consisted in several multi-temporal and multi-resolution products, including built-up area grids (GHS-BUILT), population grids (GHS-POP), settlement model (GHS-SMOD) and selected quality grids (data mask and confidence grids for GHS-BUILT).

The GHS-BUILT product is the result of a large scale experiment conducted in 2014/1025 aimed at extracting information on built-up areas from Landsat (Pesaresi et al., 2016a), producing the first multi-temporal explicit description of the evolution of built-up presence in the past 40 years. The main product is the GHS_BUILT_LDSMT_GLOBE_R2015B[3] (Pesaresi et al., 2015), and two quality grids accompany it: (1) a built-up confidence layer (GHS_BUILTt_LDSMTCNFD_GLOBE_R2015B[4]) and (2) data mask layer (GHS_BUILT_LDSMTDM_GLOBE_R2015B[5]).

The population grids (GHS_POP_GPW41MT_GLOBE_R2016A[6]) were produced in collaboration with Columbia University, Center for International Earth Science Information Network (CIESIN) in 2015, and the GHS-SMOD grids (GHS_SMOD_POP_GLOBE_R2016A[7]) present an implementation of the REGIO degree of urbanization model using as input the population grid cells.

The products from the GHS R2016 are available at GHSL collection in JRC Open Data Repository[8].

In 2017, a revised image processing workflow was implemented in the JRC Earth Observation Data and Processing Platform (JEODPP), and applied the Landsat multi-temporal imagery collection. As a result, an updated version of the multi-temporal built-up area and population grids has been produced, GHS_BUILT_LDSMT_GLOBE_R2018A and GHS_POP_GPW41MT_GLOBE_R2018A respectively. These early version of the products were distributed only for testing purposes as “preliminary” within the Community pre-Release of the GHSL Data Package 2018 (GHS CR2018) (Florczyk et al., 2018a), together with the GHS_BUILT_S1NODSM_GLOBE_R2018A.

Current data release contains the most updated products and datasets, therefore all previous releases and versions shall be treated as obsolete data.

1.4 Main Characteristics

In order to facilitate the data analytics, as it was done in the GHS P2016, the release includes a set of multi-resolution products produced by aggregation of the main products. Additionally, the density grids are produced in an equal-area projection in grids of 250 m and 1 km spatial resolution. For example, the multi-temporal population grids were produced in grids of 250 m spatial resolution, later aggregated to 1 km^2.

The main differences between the products in GHS P2016 and the current products (GHS P2019) are:

- Improved workflow for built-up area extraction from satellite image, for example, refined learning datasets (e.g., GHS_BUILT_S1NODSM_GLOBE_R2018A_V1_0), production at 30 m spatial resolution;
- Improved approach for production of population grids;
- Technical specification of the grids (i.e., the grid origin);
- Encoding of NoData values (e.g., projection domain, NoData within the data domain).
- Production of population grids in WGS 1984 coordinate system through a thorough volume-preserving warping procedure.
- Improved formulation of the settlement model GHS-SMOD with two hierarchical levels.
- Classification of administrative units from GADM 3.6 dataset based on GHS-SMOD

The subsections of the Section 2 introduce briefly each product (including more details on differences with the corresponding past version). Dedicated reports are under preparation.

[3] http://data.europa.eu/89h/jrc-ghsl-GHS_built_ldsmt_globe_r2015b
[4] http://data.europa.eu/89h/jrc-ghsl-GHS_built_ldsmtcnfd_globe_r2015b
[5] http://data.europa.eu/89h/jrc-ghsl-GHS_built_ldsmtdm_globe_r2015b
[6] http://data.europa.eu/89h/jrc-ghsl-GHS_pop_gpw4_globe_r2015a
[7] http://data.europa.eu/89h/jrc-ghsl-GHS_smod_pop_globe_r2016a
[8] http://data.jrc.ec.europa.eu/collection/ghsl

1.5 Terms of Use

JRC-GHSL-DATA@ec.europa.eu

Disclaimer: The JRC data are provided "as is" and "as available" in conformity with the JRC Data Policy[9] and the Commission Decision on reuse of Commission documents (2011/833/EU). Although the JRC guarantees its best effort in assuring quality when publishing these data, it provides them without any warranty of any kind, either express or implied, including, but not limited to, any implied warranty against infringement of third parties' property rights, or merchantability, integration, satisfactory quality and fitness for a particular purpose. The JRC has no obligation to provide technical support or remedies for the data. The JRC does not represent or warrant that the data will be error free or uninterrupted, or that all non-conformities can or will be corrected, or that any data are accurate or complete, or that they are of a satisfactory technical or scientific quality. The JRC or as the case may be the European Commission shall not be held liable for any direct or indirect, incidental, consequential or other damages, including but not limited to the loss of data, loss of profits, or any other financial loss arising from the use of the JRC data, or inability to use them, even if the JRC is notified of the possibility of such damages.

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[1] JRC Data Policy https://doi.org/10.2788/607378

2 Products

2.1 GHS built-up area grid, derived from Sentinel-1 (2016), R2018A [GHS_BUILT_S1NODSM_GLOBE_R2018A]

The Sentinel-1 product is a layer grid that contains a built-up area classification derived from Sentinel-1 backscatter images. This product increases the spatial coverage of the product produced in 2016, referred to as GHS_BUILT_S12016NODSM_GLOBE_R2016A. The same product has been distributed within the Community pre-Release of the GHSL Data Package 2018 (GHS CR2018).

The information extraction of Sentinel-1A data at global scale is described in a scientific publication (Corbane et al., 2018a). The main workflow builds on a new artificial intelligence approach for the satellite data classification process named "Symbolic Machine Learning" (SML) (Pesaresi et al., 2016a). The SML classifier automatically generates inferential rules linking the image data to available high-abstraction semantic layers used as training sets.

The SML workflow was adapted to exploit the key features of the Sentinel-1 Ground Range Detected (GRD) data which are: i) the spatial resolution of 20m with a pixel spacing of 10m and ii) the availability of dual polarisation acquisitions (VV and VH) widely used for monitoring urban areas since different polarizations have different sensitivities and different backscattering coefficients for the same target.

The learning data at the global level consisted of the union of the built-up obtained from the GHSL-Landsat for 2014 and the Global Land Cover map at 30 m resolution (GLC30). The latter has been also derived from Landsat imagery through operational visual analysis techniques (Chen *et al.*, 2015).

The massive processing of more than 7,000 Sentinel-1 scenes (Figure 1) was enabled by JEODPP platform developed in the framework of the JRC Big Data Pilot Project. The platform is set-up to answer the emerging needs of the JRC Knowledge Production units following the new challenges posed by Earth Observation entering the big data era.

Figure 1 Mosaic of the S1 scenes processed within the SML for extracting built-up areas

2.1.1 Input Data

The input imagery collection consists of Sentinel-1A (S1A) and Sentinel-1B (S1B) images:

— 5,026 S1A images from December 2015 to October 2016;

— 1,695 S1A and 329 S1B images from November 2016 to December 2017.

2.1.2 Technical Details

Author: Christina Corbane, Panagiotis Politis, Vasileios Syrris, Martino Pesaresi; Joint Research Centre (JRC) European Commission

Product name: GHS_BUILT_S1NODSM_GLOBE_R2018A

Spatial extent: Global

Temporal extent: 2016

Coordinate System: Spherical Mercator (EPSG:3857)

Resolution available: 20 m

*Encoding**: Built-up area classification map (integer) [0,1];

Data organisation (*): VRT file (with TIFF tiles); pyramids; SHP file of the tile schema. **ArcGIS users of the 30 m product: *ESRI.vrt. file**

The grid is provided as a VRT file (with GeoTIFF tiles), and with pyramids. Table 1 below outlines the technical characteristics of the datasets pre-Released in this data package.

Table 1. Technical details of the datasets in GHS_BUILT_S1NODSM_GLOBE_R2018A

GHS_BUILT_S1NODSM_GLOBE_R2018A			
ID	**Description**	**Resolution (projection)**	**Size**
GHS_BUILT_S1NODSM _GLOBE_R2018A _3857_20_V1_0.vrt	Classification map depicting built-up presence. 0 = no built-up or no data 1 = built-up are **ArcGIS users: *ESRI.vrt.file**	20 m (Pseudo Mercator)	8.6 GB

2.1.3 How to cite

Dataset:

Corbane, Christina; Politis, Panagiotis; Syrris, Vasileios; Pesaresi, Martino (2018): GHS built-up grid, derived from Sentinel-1 (2016), R2018A. European Commission, Joint Research Centre (JRC) doi:10.2905/jrc-ghsl-10008 PID: http://data.europa.eu/89h/jrc-ghsl-10008

Concept & Methodology:

Corbane, Christina; Pesaresi, Martino; Politis, Panagiotis; Syrris, Vasileios; Florczyk, Aneta J.; Soille, Pierre; Maffenini, Luca; Burger, Armin; Vasilev, Veselin; Rodriguez, Dario; Sabo, Filip; Dijkstra, Lewis; Kemper, Thomas (2017): Big earth data analytics on Sentinel-1 and Landsat imagery in support to global human settlements mapping, Big Earth Data, 1:1-2, 118-144, DOI: 10.1080/20964471.2017.1397899

2.2 GHS built-up area grid (GHS-BUILT), derived from Landsat, multi-temporal (1975-1990-2000-2014), R2018A [GHS_BUILT_LDSMT_GLOBE_R2018A]

The Landsat product contains a set of multi-temporal and multi-resolution grids. The main product is the multi-temporal classification layer on built-up presence derived from the Global Land Survey (GLS) Landsat[10] image collections (GLS1975, GLS1990, GLS2000, and ad-hoc Landsat 8 collection 2013/2014). This data release contains version 2.0 of the product which is an updated version of the one distributed within the Community pre-Release of the GHSL Data Package 2018 (GHS CR2018).

2.2.1 Improvements comparing to the previous version

The satellite-derived information extraction tasks included in the GHSL production workflow used to produce the products GHS_BUILT_LDSMT_GLOBE_R2015B and GHS_BUILT_LDSMT_GLOBE_R2018A, builds on the Symbolic Machine learning (SML) method that was designed for remote sensing big data analytics (Pesaresi et al., 2016b). For the purpose of the GHS_BUILT_LDSMT_GLOBE_R2018A, a revised image processing workflow was implemented in the JRC Earth Observation Data and Processing Platform (JEODPP).

Comparing to the previous publicly released version (R2015B), these datasets include a number of improvements, as shown through visual comparison in Figure 2. Such improvement are:

- Improved spatial coverage (additional Landsat 8 scenes)
- Improved spatial resolution (30 m)
- Improved methods (e.g., improved learning data set), which resulted in:
    - Reduction in omission error (i.e. more built-up areas were detected)
    - Reduction in commission error (i.e. less detection of false built-up areas)

Corbane et al., (2019) explains in detail the rationale, the workflow deployed to generate the layer, mainly the usage of the GHSL Sentinel-1 data set (GHS_BUILT_S1NODSM_GLOBE_R2018A) as a learning dataset, and the multi-temporal validation of the layer.

2.2.2 Input Data

The new product GHS_BUILT_LDSMT_GLOBE_R2018A (version 2.0) is based on 33,202 images (Florczyk et al., 2018b) organized in four Landsat data collections centred at 1975, 1990, 2000 and 2014 that were processed with the SML classifier as follows:

- 7,597 scenes acquired by the Multispectral Scanner (collection 1975);
- 7,375 scenes acquired by the Landsat 4-5 Thematic Mapper (TM) (collection 1990);
- 8,788 scenes acquired by the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) (collection 2000) and;
- 9,442 scenes acquired by Landsat 8 (collection 2014).

2.2.3 Technical Details

Author: Christina Corbane, Aneta .J. Florczyk, Martino Pesaresi, Panagiotis Politis, Vasileius Syrris; Joint Research Centre (JRC) European Commission

Product name: GHS_BUILT_LDSMT_GLOBE_R2018A

Spatial extent: Global

Temporal extent: 1975-1990-2000-2014

*Coordinate Systems**: Spherical Mercator (EPSG:3857), World Mollweide (EPSG:54009)

*Resolutions available**: 30 m, 250 m, 1 km

[10] http://glcf.umd.edu/data/gls/

*Encoding**: Multi-temporal built-up area classification map (integer): [1,6], NoData: 0; Built-up density grid (float32): [0-100], NoData [-200]

Data organisation (*): VRT file (with GeoTIFF tiles) or GeoTIFF files; as single global layers, with pyramids and SHP file of tile schema, or tiled; **ArcGIS users of the 30 m product: *ESRI.vrt.file**.

Table 2 outlines the technical characteristics of the datasets released in this data package.

(*) product dependent, see Table 2. Disclaimer: the re-projection of the World Mollweide version of the GHS_BUILT_LDSMT_GLOBE_R2018A to coordinate systems requires specific technical knowledge. No responsibility is taken for workflows developed independently by users.

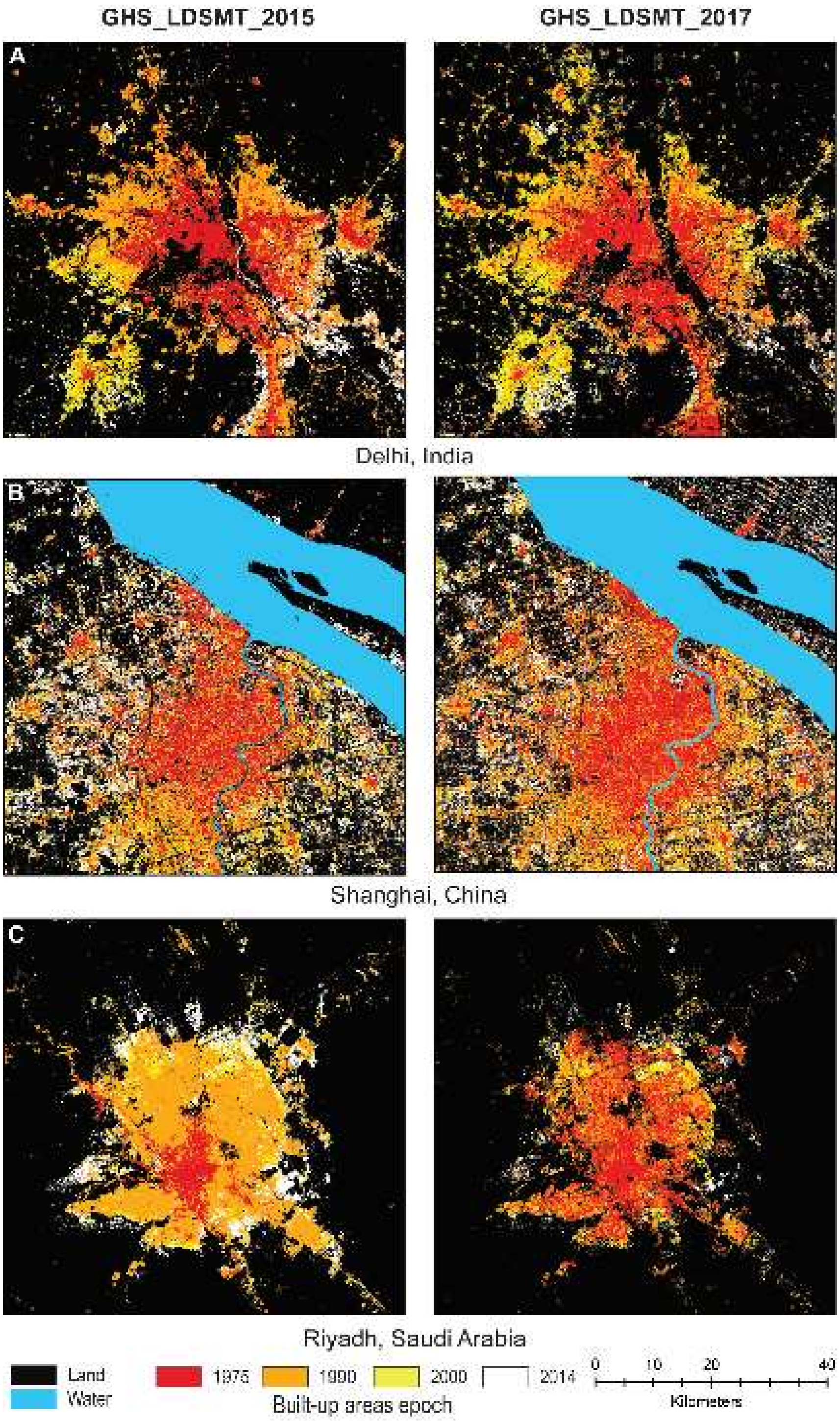

Figure 2 Comparison between GHS_BUILT_LDSMT_GLOBE_R2015B (left panel – GHS_LDSMT_2015) and GHS_BUILT_LDSMT_GLOBE_R2018A, version 2.0 (right panel – GHS_LDSMT_2017). In Corbane et al. (2019)

Table 2. Technical details of the datasets in GHS_BUILT_ LDSMT_GLOBE_R2018A

GHS_BUILT_LDSMT_GLOBE_R2018A			
ID	**Description**	**Resolution (projection)**	**Size**
GHS_BUILT_LDSMT _GLOBE_R2018A _3857_30_V2_0	Multi-temporal classification of built-up presence. 0 = no data 1 = water surface 2 = land no built-up in any epoch 3 = built-up from 2000 to 2014 epochs 4 = built-up from 1990 to 2000 epochs 5 = built-up from 1975 to 1990 epochs 6 = built-up up to 1975 epoch **ArcGIS users: *ESRI.vrt.file**	30 m (Pseudo Mercator)	4.3 GB
GHS_BUILT_LDS2014 _GLOBE_R2018A _54009_250_V2_0	Built-up area density for epoch 2014, aggregated from 30 m. Values are expressed as decimals (Float) from 0 to 100 NoData [-200]: -200 – out of projection domain or NoData	250 m (World Mollweide)	398 MB
GHS_BUILT_LDS2000 _GLOBE_R2018A _54009_250_V2_0	Built-up area density for epoch 2000, aggregated from 30 m. Values are expressed as decimals (Float) from 0 to 100 NoData [-200]: -200 – out of projection domain or NoData	250 m (World Mollweide)	353 MB
GHS_BUILT_LDS1990 _GLOBE_R2018A _54009_250_V2_0	Built-up area density for epoch 1990, aggregated from 30 m. Values are expressed as decimals (Float) from 0 to 100 NoData [-200]: -200 – out of projection domain or NoData	250 m (World Mollweide)	316 MB
GHS_BUILT_LDS1975 _GLOBE_R2018A _54009_250_V2_0	Built-up area density for epoch 1975, aggregated from 30 m. Values are expressed as decimals (Float) from 0 to 100 NoData [-200]: -200 – out of projection domain or NoData	250 m (World Mollweide)	274 MB
GHS_BUILT_LDS2014 _GLOBE_R2018A _54009_1K_V2_0	Built-up area density for epoch 2014, aggregated from 30 m. Values are expressed as decimals (Float) from 0 to 100 NoData [-200]: -200 – out of projection domain or NoData	1 km (World Mollweide)	86 MB
GHS_BUILT_LDS2000 _GLOBE_R2018A _54009_1K_V2_0	Built-up area density for epoch 2000, aggregated from 30 m. Values are expressed as decimals (Float) from 0 to 100 NoData [-200]: -200 – out of projection domain or NoData	1 km (World Mollweide)	76 MB
GHS_BUILT_LDS1990 _GLOBE_R2018A _54009_1K_V2_0	Built-up area density for epoch 1990. Aggregated from 30 m. Values are expressed as decimals (Float) from 0 to 100 NoData [-200]: -200 – out of projection domain or NoData	1 km (World Mollweide)	68 MB
GHS_BUILT_LDS1975 _GLOBE_R2018A _54009_1K_V2_0	Built-up area density for epoch 1975. Aggregated from 30 m. Values are expressed as decimals (Float) from 0 to 100 NoData [-200]: -200 – out of projection domain or NoData	1 km (World Mollweide)	58 MB

2.2.4 Summary statistics

Table 3 Summary statistics of total global built-up area in square kilometre as obtained from the 1-km World Mollweide grid (Corbane et al., 2019)

	1975	1990	2000	2014
Built-up area (km^2)	379,552	523,333	655,742	789,385

2.2.5 How to cite

Dataset:

Corbane, Christina; Florczyk, Aneta; Pesaresi, Martino; Politis, Panagiotis; Syrris, Vasileios (2018): GHS built-up grid, derived from Landsat, multitemporal (1975-1990-2000-2014), R2018A. European Commission, Joint Research Centre (JRC) doi:10.2905/jrc-ghsl-10007 PID: http://data.europa.eu/89h/jrc-ghsl-10007

Concept & Methodology:

Corbane, Christina., Pesaresi, Martino., Kemper, Thomas., Politis, Panagiotis., Florczyk, Aneta J., Syrris, Vasileios, Melchiorri, Michele, Sabo, Filip, and Soille, Pierre (2019). Automated global delineation of human settlements from 40 years of Landsat satellite data archives. Big Earth Data 3, 140–169. DOI:10.1080/20964471.2019.1625528

2.3 GHS population grid (GHS-POP), derived from GPW4.10, multi-temporal (1975-1990-2000-2015), R2019A [GHS_POP_MT_GLOBE_R2019A]

This spatial raster product depicts the distribution and density of population (Figure 3), expressed as the number of people per cell. Residential population estimates for target years 1975, 1990, 2000 and 2015 provided by CIESIN Gridded Population of the World, version 4.10 (GPWv4.10) at polygon level, were disaggregated from census or administrative units to grid cells, informed by the distribution and density of built-up as mapped in the Global Human Settlement Layer (GHSL) global layer per corresponding epoch. The disaggregation methodology is described in a conference scientific paper (Freire et al., 2016)). This an updated version of the product (GHS_POP_GPW41MT_GLOBE_R2018A) distributed within the Community pre-Release of the GHSL Data Package 2018 (GHS CR2018).

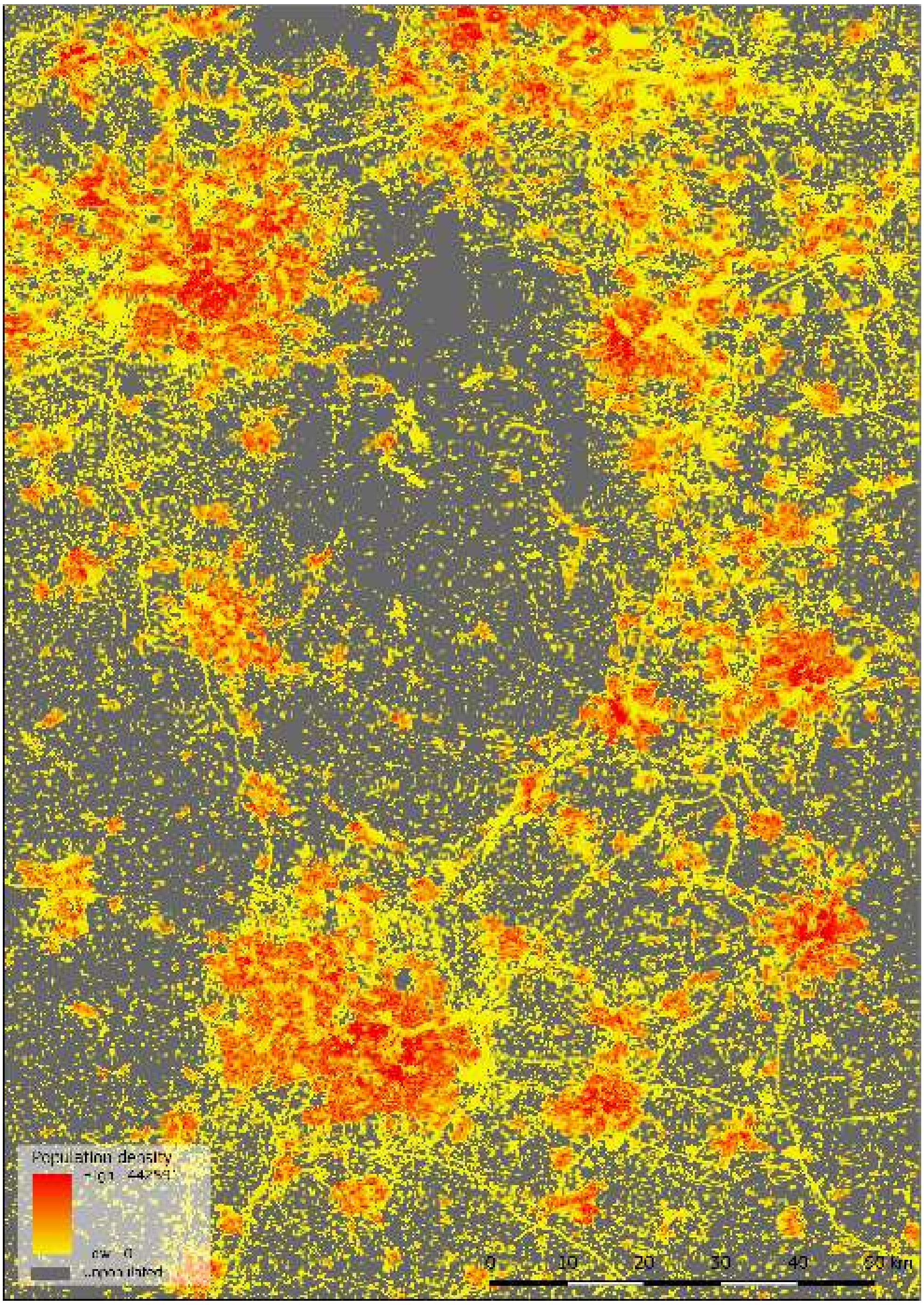

Figure 3 GHS Population grid (GHS-POP) GHS_POP_E2015_GLOB_R2019A_54009_250_V1_0 displayed in West Midlands (United Kingdom).

2.3.1 Improvements comparing to the previous version

The new version of the GHSL population distribution grids aimed at incorporating improvements originating from input datasets, namely population estimates and built-up presence. While the disaggregation relied essentially on the same clear and simple approach, there were significant differences to the input data that had a positive effect on the final quality and accuracy of population grids. Here, we describe the main differences between the currently released products (GHS_POP_MT_GLOBE_R2019A) and the previous one (GHS_POP_GPW41_GLOBE_R2015A), for more information on these improvements, see the related scientific publication (Freire et al., 2018).

For the new GHS-POP (GHS_POP_MT_GLOBE_R2019A), the new Landsat based GHS-BUILT (GHS_BUILT_LDSMT_GLOBE_R2018A, version 2.0) was used as target for disaggregation of population estimates. Cells declared as "NoData" in built-up layers were treated as zero for population disaggregation.

The base source of population estimates (both counts and geometries) for the four epochs mapped was the Gridded Population of the World, version 4.10 (GPWv4.10), from CIESIN/SEDAC. Respect to the previous release of GHSL Data Package 2016 (GHS P2016), this release used GPW source data that incorporated boundary or population updates for 67 countries.

Due to the previous GHSL population grids being produced in last quarter of 2015, before the final GPWv4 data set was fully assembled, more changes were included in population sources in the current release than those incorporated in the GPW data between GPWv4 and the current GPWv4.10. For detailed information on what has changed in GPWv4.10, refer to:

https://sedac.ciesin.columbia.edu/data/collection/gpw-v4/whatsnewrev10

GHS-POP product is produced in Mollweide at 250 m, and then aggregated at 1 km. These two datasets are then warped to WGS 1984 coordinate system, at 9 arcsec and 30 arcsec resolution respectively, by applying a thorough volume-preserving procedure (i.e. oversampling at 10-times higher resolution; transformation of raster to points, using cell centroids; vector warping to WGS 1984; and rasterization in the final grid by adding point values per pixel).

2.3.1.1 Harmonisation of Coastlines

Seashore and waterfront can be especially intense and dynamic zones, contributing to making census or administrative geometries outdated and inaccurate. Inconsistencies between census data and GHSL along coastlines (including inland water bodies) were detected and reconciled accordingly. The high-resolution GHSL layer on built-up areas for 2014 (from R2015B) was used to detect significant human presence (i.e. built-up areas presence) beyond censuses' coastlines and these lines were reconciled accordingly. This harmonization was carried out in the following countries:

Albania	France	Singapore
Austria	Guinea-Bissau	Sweden
Azerbaijan	Iceland	Tunisia
Bulgaria	Japan	Ukraine
Bahrain	Republic of Korea	USA
Switzerland	Malaysia	Venezuela
Germany	Netherlands	Viet Nam
Denmark	Norway	
United Arab Emirates	Romania	
Finland	Russia	

2.3.1.2 *Revision of Unpopulated Areas*

Units deemed as "uninhabited" in the census data were critically assessed for presence of residential population, based on ancillary data and high-resolution imagery. Inconsistencies between census data and contradicting evidence were detected and reconciled accordingly. An automated method was devised to split and merge these polygons, based on geographical proximity, with those ones adjacent and containing population. This procedure was implemented while minimizing changes to source geometry, preserving the regional distribution of population, and the overall counts. This procedure was carried out in the following countries:

- Afghanistan
- Armenia
- Democratic Republic of the Congo
- Colombia
- Cyprus
- Egypt
- Georgia
- Guyana
- Iraq
- Lebanon
- Mali
- Malawi
- Nepal
- Rwanda
- Thailand
- Ukraine

2.3.2 Input Data

The new product GHS_BUILT_LDSMT_GLOBE_R2018A (version 2.0) was used as target for disaggregation of population estimates. The base source of population estimates for the four epochs was the Gridded Population of the World, version 4.10 (GPWv4.10), from CIESIN/SEDAC, with some modifications as described above.

2.3.3 Technical Details

Author: Sergio Freire, Marcello Schiavina, Joint Research Centre (JRC) European Commission; *Kytt MacManus* Columbia University, Center for International Earth Science Information Network - CIESIN.

Product name: GHS_POP_MT_GLOBE_R2019A

Spatial extent: Global

Temporal extent: 1975-1990-2000-2015

Coordinate Systems: World Mollweide (EPSG: 54009) and WGS 1984 (EPSG: 4326)

Resolutions available: 250 m, 1 km, 9 arcsec, 30 arcsec

Encoding: Population data float32 [0, ∞); NoData: -200

Data organisation: The grids are provided as GeoTIFF file as single global layer with pyramids or tiled.

Table 4 outlines the technical characteristics of the datasets released in this data package.

Table 4. Technical details of the datasets in GHS_POP_MT_GLOBE_R2019A

GHS_POP_MT_GLOBE_R2019A			
ID	**Description**	**Resolution (Projection/Coordinate system)**	**Size**
GHS_POP_E2015_ GLOBE_R2019A _54009_250_V1_0	Population density for epoch 2015 Values are expressed as decimals (Float) from 0 to 442591 NoData [-200]	250 m (World Mollweide)	515 MB
GHS_POP_E2000_ GLOBE_R2019A _54009_250_V1_0	Population density for epoch 2000 Values are expressed as decimals (Float) from 0 to 303161 NoData [-200]	250 m (World Mollweide)	476 MB
GHS_POP_E1990_ GLOBE_R2019A _54009_250_V1_0	Population density for epoch 1990 Values are expressed as decimals (Float) from 0 to 237913 NoData [-200]	250 m (World Mollweide)	451 MB

GHS_POP_MT_GLOBE_R2019A			
ID	**Description**	**Resolution (Projection/Coordinate system)**	**Size**
GHS_POP_E1975 _GLOBE_R2019A _54009_250_V1_0	Population density for epoch 1975 Values are expressed as decimals (Float) from 0 to 899329 NoData [-200]	250 m (World Mollweide)	427 MB
GHS_POP_E2015 _GLOBE_R2019A _54009_1K_V1_0	Population density for epoch 2015 Values are expressed as decimals (Float) from 0 to 442591 NoData [-200]	1 km (World Mollweide)	124 MB
GHS_POP_E2000 _GLOBE_R2019A _54009_1K_V1_0	Population density for epoch 2000 Values are expressed as decimals (Float) from 0 to 341997 NoData [-200]	1 km (World Mollweide)	121 MB
GHS_POP_E1990 _GLOBE_R2019A _54009_1K_V1_0	Population density for epoch 1990 Values are expressed as decimals (Float) from 0 to 1013921 NoData [-200]	1 km (World Mollweide)	120 MB
GHS_POP_E1975 _GLOBE_R2019A _54009_1K_V1_0	Population density for epoch 1975 Values are expressed as decimals (Float) from 0 to 3017848 NoData [-200]	1 km (World Mollweide)	122 MB
GHS_POP_E2015 _GLOBE_R2019A _4326_9SS_V1_0	Population count for epoch 2015 Values are expressed as decimals (Float) from 0 to 302832 NoData [-200]	9 arcsec (WGS84)	1.52 GB
GHS_POP_E2000 _GLOBE_R2019A _4326_9SS_V1_0	Population count for epoch 2000 Values are expressed as decimals (Float) from 0 to 209939 NoData [-200]	9 arcsec (WGS84)	1.50 GB
GHS_POP_E1990 _GLOBE_R2019A _4326_9SS_V1_0	Population count for epoch 1990 Values are expressed as decimals (Float) from 0 to 164755 NoData [-200]	9 arcsec (WGS84)	1.53 GB
GHS_POP_E1975 _GLOBE_R2019A _4326_9SS_V1_0	Population count for epoch 1975 Values are expressed as decimals (Float) from 0 to 611544 NoData [-200]	9 arcsec (WGS84)	1.58 GB
GHS_POP_E2015 _GLOBE_R2019A _4326_30SS_V1_0	Population count for epoch 2015 Values are expressed as decimals (Float) from 0 to 459435 NoData [-200]	30 arcsec (WGS84)	240 MB
GHS_POP_E2000 _GLOBE_R2019A _4326_30SS_V1_0	Population count for epoch 2000 Values are expressed as decimals (Float) from 0 to 303161 NoData [-200]	30 arcsec (WGS84)	237 MB
GHS_POP_E1990 _GLOBE_R2019A _4326_30SS_V1_0	Population count for epoch 1990 Values are expressed as decimals (Float) from 0 to 650409 NoData [-200]	30 arcsec (WGS84)	241 MB
GHS_POP_E1975 _GLOBE_R2019A _4326_30SS_V1_0	Population count for epoch 1975 Values are expressed as decimals (Float) from 0 to 2109200 NoData [-200]	30 arcsec (WGS84)	247 MB

2.3.4 Summary statistics

Table 5 Summary statistics of total population as obtained from the 1-km World Mollweide grid as obtained from GPW4.10 - total population adjusted to the UN WPP 2015 (United Nations, Department of Economic and Social Affairs, Population Division, 2015).

	1975	1990	2000	2015
Total Population	4,061,348,355	5,309,597,005	6,126,529,207	7,349,329,050

2.3.5 How to cite

Dataset:

Schiavina, Marcello; Freire, Sergio; MacManus, Kytt (2019): GHS population grid multitemporal (1975-1990-2000-2015), R2019A. European Commission, Joint Research Centre (JRC) [Dataset] doi:[10.2905/0C6B9751-A71F-4062-830B-43C9F432370F](https://doi.org/10.2905/0C6B9751-A71F-4062-830B-43C9F432370F) PID: http://data.europa.eu/89h/0c6b9751-a71f-4062-830b-43c9f432370f

Concept & Methodology:

Freire, Sergio; MacManus, Kytt; Pesaresi, Martino; Doxsey-Whitfield, Erin; Mills, Jane (2016): Development of new open and free multi-temporal global population grids at 250 m resolution. Geospatial Data in a Changing World; Association of Geographic Information Laboratories in Europe (AGILE). AGILE 2016.

2.4 GHS Settlement Model layers (GHS-SMOD), derived from GHS-POP and GHS-BUILT, multi-temporal (1975-1990-2000-2015), R2019A [GHS_SMOD_POPMT_GLOBE_R2019A]

The GHS Settlement Model layers (GHS-SMOD) GHS_SMOD_POPMT_GLOBE_R2019A delineate and classify settlement typologies (Figure 4) via a logic of cell clusters population size, population and built-up area densities as a refinement of the 'degree of urbanisation' method as described by EUROSTAT[11]. The GHS-SMOD is derived from the GHS-POP (GHS_POP_MT_GLOBE_R2019A, version 1.0) and GHS-BUILT (GHS_BUILT_LDSMT_GLOBE_R2018A, version 2.0) released within this GHSL Data Package 2019 (GHS P2019).

The GHS Settlement Model layers (GHS-SMOD) GHS_SMOD_POPMT_GLOBE_R2019A is composed by two datasets: the GHS-SMOD raster grid and the urban centre entities vector. The first is a raster grid representing the settlement classification per grid cell and the second delineates the urban centre boundaries, with main attributes, in a vector file.

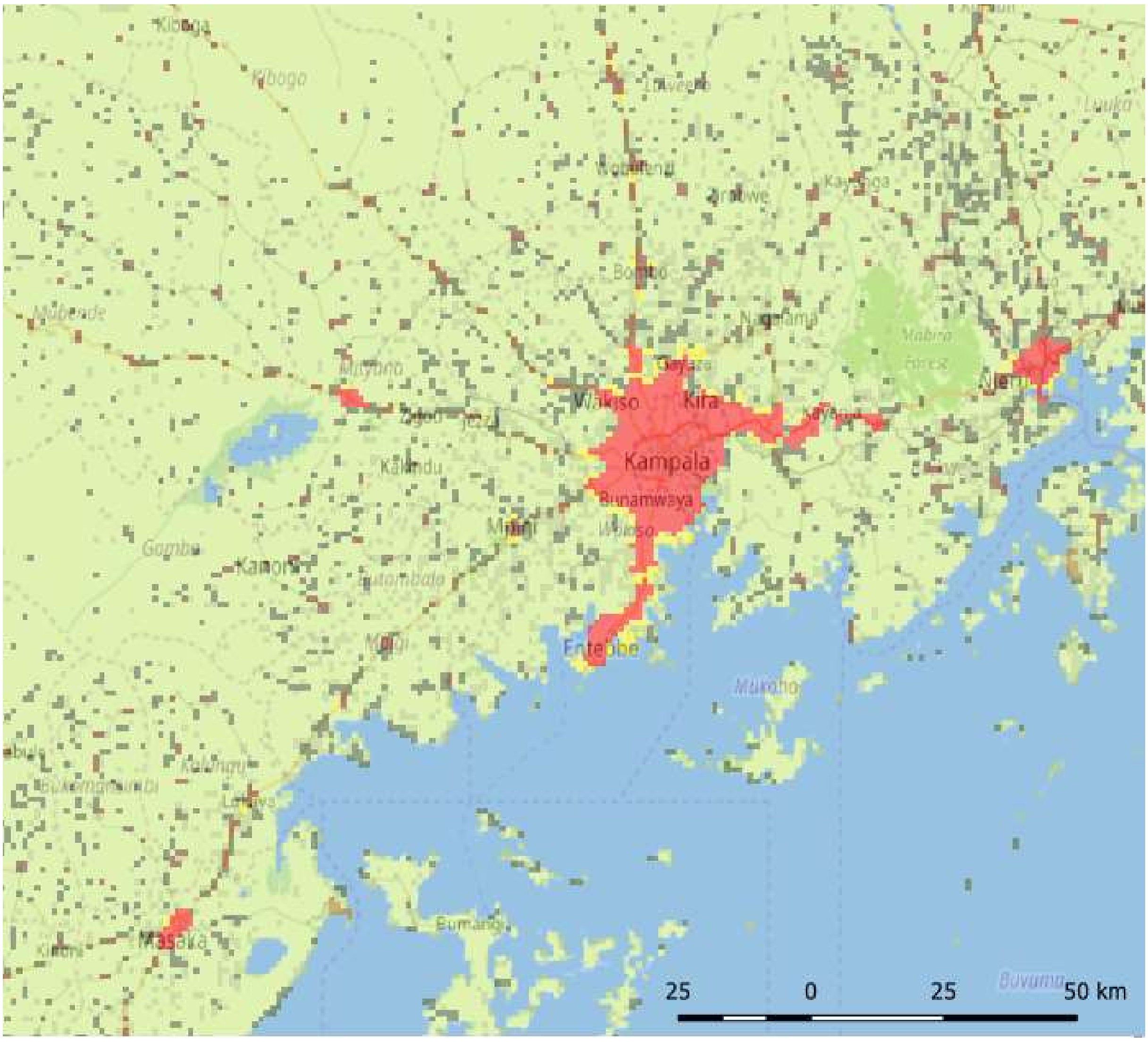

Figure 4 GHS Settlement Model grid (GHS-SMOD) GHS_SMOD_POP2015_GLOBE_R2019A_54009_1K_V2_0 displayed in the area of Kampala (Uganda) –Legend in Table 7. The boundaries and the names shown on this map do not imply official endorsement or acceptance by the European Union © OpenStreetMap

[11] https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Degree_of_urbanisation

2.4.1 Improvements comparing to the previous version

The GHS-SMOD grid is an improvement of the GHS-SMOD R2016A introducing a more detailed classification of settlements in two levels, with a further development of the GHSL Settlement Model (GHSL SMOD). The GHS-SMOD is provided at the detailed level (Second Level - L2). First level, as a porting of the Degree of Urbanization adopted by EUROSTAT can be obtained aggregating L2 as shown in the first level (L1) description (see Table 6 p. 22).

2.4.2 GHSL Settlement model (GHSL SMOD)

The *GHSL Settlement Model* (GHSL SMOD) is the porting of the DEGURBA in the Global Human Settlement Layer (GHSL) framework developed by the European Commission, Joint Research Centre[12]. The GHSL SMOD supports the international multi-stakeholder discussion on the DEGURBA operationalization parameters and on the DEGURBA derived metrics and indicators using the GHSL baseline information as common global data frame (European Commission , Joint Research Centre, 2018; Melchiorri et al., 2018; Corbane et al., 2018b; Melchiorri et al., 2019). The general GHSL SMOD operates in seven optional modalities (01 to 07), ordered from low to high number of model assumptions and necessary input data complexity (Maffenini et al., 2019). This approach was designed in order to provide a scalable solution able to support different user requirements and to operate in different and non-GHSL data ecosystems not necessarily compliant with the GHSL data technical specifications and quality control procedures. The GHS-SMOD grid is produced using the option 6 (O6) which assumptions are listed below with a short description:

- ***Basic criteria*** (local population densities: 50, 300 and 1500; cluster 4-connectivity cluster rule; cluster population size: 500, 5K, 50K) – they are the basic criteria shaping the GHSL Settlement model (as in the DEGURBA method) as grid population density, grid cluster population size, and connectivity rule to form grid cell clusters.
    - Urban Centres use population density of 1500 inhabitants per km^2 and cluster population size of 50k inhabitants;
    - Urban Clusters use population density of 300 inhabitants per km^2 and cluster population size of 5k inhabitants;
    - Rural Clusters use population density of 300 inhabitants per km^2 and cluster population size of 500 inhabitants;
    - Low density Rural grid cells use population density of 50 inhabitants per km^2.
- ***Permanent water surface excluded*** - all cells with at least 0.5 share of permanent water surface not populated nor built, are classified as "Water grid cells", to exclude from the settlement classification at the second hierarchical level areas that are not on land.
- ***Density on permanent land*** –the densities values used in the GHSL SMOD are calculated using the permanent land surface portion inside the unitary surface of the spatial unit (grid cell).
- ***xbu_share 50%*** - the Urban Centres are set by adding to the basic criteria (see point above) also those cells with at least 50% of built-up surface. This assumption is useful for accommodating the presence in the city of large areas with low resident inhabitants but strongly functionally linked with the city, as for example large productive or commercial areas (typical case of cities in Unites States of America). As the basic criteria defines Urban Centres to be fully contained into Urban Clusters and the application of *xbu_share 50%* rule would break this hierarchy, this assumption extends the Urban Cluster domain to contain Urban Centres.
- ***Generalization of HDC (smooth and gap filling)*** –the clusters of the Urban Centres set by the density cut-off value it is spatially generalized by iterative majority filtering process done with a kernel of 3x3 kilometres until idempotence it is reached. Moreover, the remaining holes within the Urban Centre perimeter after the smoothing are filled if they are smaller than 15 km^2 in surface. The effect of this assumption is that Urban Centres as derived from the input GRIDS are more compact and simple in shape, then easier to translate to GIS POLYGON entities. Ideal typical case is the inclusion of large parks (less than 15 km^2) or low-density population areas within the "Urban Centre" perimeter because completely surrounded by GRID samples with high density belonging to the "Urban Centre" class.

[12] https://ghsl.jrc.ec.europa.eu/

- ***xbu_share 3%*** - candidate samples for the "Urban Cluster" domain are accepted only if they exhibit a built-up surface share greater than 0.03. Grid cells are included in the urban cluster domain only if some minimal evidences of physical built-up structure was recorded by an independent source respect to census data. The purpose of this assumption is to increase the robustness of the GHSL SMOD response by forcing consistency between census-derived sources (population grids) and land cover / land use sources (built-up areas) mitigating the effect of misalignment, thematic bias, scale gaps or other data gaps that may be present in the data.

2.4.3 GHS-SMOD classification rules

With the described set of assumptions (GHSL SMOD 06), at the first hierarchical level (L1), the GHSL SMOD classifies the 1 km^2 grid cells by identifying the following spatial entities: a) "Urban Centre", b) "Urban Cluster" and classifying all the other cells as "Rural Grid Cells".

The criteria for the definition of the **spatial entities** at the first hierarchical level are:

- ***"Urban Centre" (also "High Density Cluster" - HDC)*** - An Urban Centre consists of contiguous grid cells (4-connectivity cluster) with a density of at least 1,500 inhabitants per km^2 of permanent land or with a built-up surface share on permanent land greater than 0.5, and has at least 50,000 inhabitants in the cluster with smoothed boundaries and <15 km^2 holes filled;
- ***"Urban Cluster" (also "Moderate Density Cluster" - MDC)*** - An Urban Cluster consists of contiguous grid cells (4-connectivity cluster) with a density of at least 300 inhabitants per km^2 of permanent land, a built-up surface share on permanent land greater than 0.03 and has at least 5,000 inhabitants in the cluster plus all contiguous (4-connectivity cluster) Urban Centres (see section 2.4.2 for details).

The ***"Rural grid cells" (also "Mostly Low Density Cells" - LDC)*** are all the other cells that do not belong to an Urban Cluster. Most of these will have a density below 300 inhabitants per km^2 (grid cell). Some Rural grid cells may have a higher density, but they are not part of cluster with sufficient population to be classified as an Urban Cluster.

The **settlement grid** at level 1 represents these definitions on a layer grid. Each pixel is classified using the following set of codes (classes) and rules:

— ***Class 3: "Urban Centre grid cell"***, if the cell belongs to an Urban Centre;

— ***Class 2: "Urban Cluster grid cell"***, if the cell belongs to an Urban Cluster and not to an Urban Centre;

— ***Class 1: "Rural grid cell"***, if the cell does not belong to an Urban Cluster.

The second hierarchical level of the GHSL SMOD (L2) is a refinement of the DEGURBA set up to identify smaller settlements. It follows the same approach based on population density, population size and contiguity with a nested classification into the first hierarchical level. At the second hierarchical level, the GHSL SMOD classifies the 1 km^2 grid cells by identifying the following spatial entities: a) "Urban Centres" as at the first level; b) "Dense Urban Cluster" and c) "Semi-dense Urban Cluster" as parts of the "Urban Cluster", classifying all the other cells of "Urban Clusters" as "Suburban or peri-urban grid cells"; and identifying d) "Rural Cluster" within the "Rural grid cells". All the other cells belonging to the "Rural grid cells" are classified as "Low Density grid cells" or "Very Low Density grid cells" according to their cell population (Figure 5).

The basic criteria for the definition of the **spatial entities** at the second hierarchical level are:

- ***"Urban Centre" (also "Dense, Large Settlement" or "High Density Cluster" - HDC)*** - An Urban Centre consists of contiguous grid cells (4-connectivity cluster) with a density of at least 1,500 inhabitants per km^2 of permanent land or with a built-up surface share on permanent land greater than 0.5, and has at least 50,000 inhabitants in the cluster with smoothed boundaries and <15 km^2 holes filled;
- ***"Dense Urban Cluster" (also "Dense, Medium Cluster")*** – A Dense Urban Cluster consists of contiguous grid cells (4-connectivity cluster) with a density of at least 1,500 inhabitants per km^2 of permanent land or with a built-up surface share on permanent land greater than 0.5, and has at least 5,000 inhabitants in the cluster;

- ***"Semi-dense Urban Cluster" (also "Semi-dense, Medium Cluster")*** - A Semi-dense Urban Cluster consists of contiguous grid cells (4-connectivity cluster) with a density of at least 300 inhabitants per km^2 of permanent land, a built-up surface share on permanent land greater than 0.03, has at least 5,000 inhabitants in the cluster and is at least 3-km away from other Urban Clusters;
- ***"Rural cluster" (also "Semi-dense, Small Cluster")*** - A Rural Cluster consists of contiguous cells (4-connectivity cluster) with a density of at least 300 inhabitants per km^2 of permanent land and has at least 500 and less than 5,000 inhabitants in the cluster.

The ***"Suburban or peri-urban grid cells" (also Semi-dense grid cells)*** are all the other cells that belong to an Urban Cluster (level 1 spatial entity) but are not part of a Urban Centre, Dense Urban Cluster or a Semi-dense Urban Cluster.

The ***"Low Density Rural grid cells" (also "Low Density grid cells")*** are Rural grid cells with a density of at least 50 inhabitants per km^2 (grid cell) and are not part of a Rural Cluster.

The ***"Very low density rural grid cells" (also "Very Low Density grid cells")*** are cells with a density of less than 50 inhabitants per km^2 (grid cell).

The ***"Water grid cells"*** are all the cells with more than 0.5 share covered by permanent surface water not populated nor built.

The **settlement grid** at level 2 represents these definitions on a single layer grid. Each pixel is classified using the following set of codes (classes) and rules (Table 7):

— ***Class 30: "Urban Centre grid cell"***, if the cell belongs to an Urban Centre spatial entity;

— ***Class 23: "Dense Urban Cluster grid cell"***, if the cell belongs to a Dense Urban Cluster spatial entity;

— ***Class 22: "Semi-dense Urban Cluster grid cell"***, if the cell belongs to a Semi-dense Urban Cluster spatial entity;

— ***Class 21: "Suburban or per-urban grid cell"***, if the cell belongs to an Urban Cluster cells at first hierarchical level but is not part of a Dense or Semi-dense Urban Cluster;

— ***Class 13: "Rural cluster grid cell"***, if the cell belongs to a Rural Cluster spatial entity;

— ***Class 12: "Low Density Rural grid cell"***, if the cell is classified as Rural grid cells at first hierarchical level, has more than 50 inhabitant and is not part of a Rural Cluster;

— ***Class 11: "Very low density rural grid cell"***, if the cell is classified as Rural grid cells at first hierarchical level, has less than 50 inhabitant and is not part of a Rural Cluster;

— ***Class 10: "Water grid cell"***, if the cell has 0.5 share covered by permanent surface water and is not populated nor built.

2.4.4 GHS-SMOD spatial entities naming

The highest tier spatial entities (Urban Centre) are named using an algorithm that automatically queries the GISCO and the full OpenStreetMap datasets with the following steps:

1 For each node of the dataset the reference name is selected among all the available naming tag with the following priority: *name_en*; *name_int*; *name* (if in Latin characters); *name_fr*; *name_es; name_it*; *name_de*; *name_wiki*; *name;*

2 The algorithm filters all nodes that overlaps the extent of the spatial entity in their 3 km buffer and selects among them the nodes with the highest priority using the following tag ordering (*key:value*): *place:city*; *place:town*; *place:village*; *place:hamlet*; *place:isolated_dwelling*; *place:farm*; *place:allotments*; *place:borough*; *place:suburb*; *place:quarter*; *place:neighbourhood*; *place:city_block*; *place:plot*; *place:locality*; *place:municipality*; *place:civil_parish*; *railway:station*; *addr:city*;

3 If a single node is selected the reference name is assigned to the spatial entity as main name; if multiple nodes are selected the function ranks the nodes by *population* tag values (descending order, absence of *population* tag equal 0); if no *population* tag is present, it ranks by sum of GHS-POP in the 5 km buffer around the point (descending order). The ordered list is saved and assigned to the spatial entity; the first name is selected as main name of the spatial entity.

4 If any node filtered at point 2 has the *capital* tag equal to *yes*, *1*, *2*, *3*, or *4*, the reference name is marked as capital. If this differs from the main name assigned at point 3, the capital name is concatenated to the main name, between square brackets.

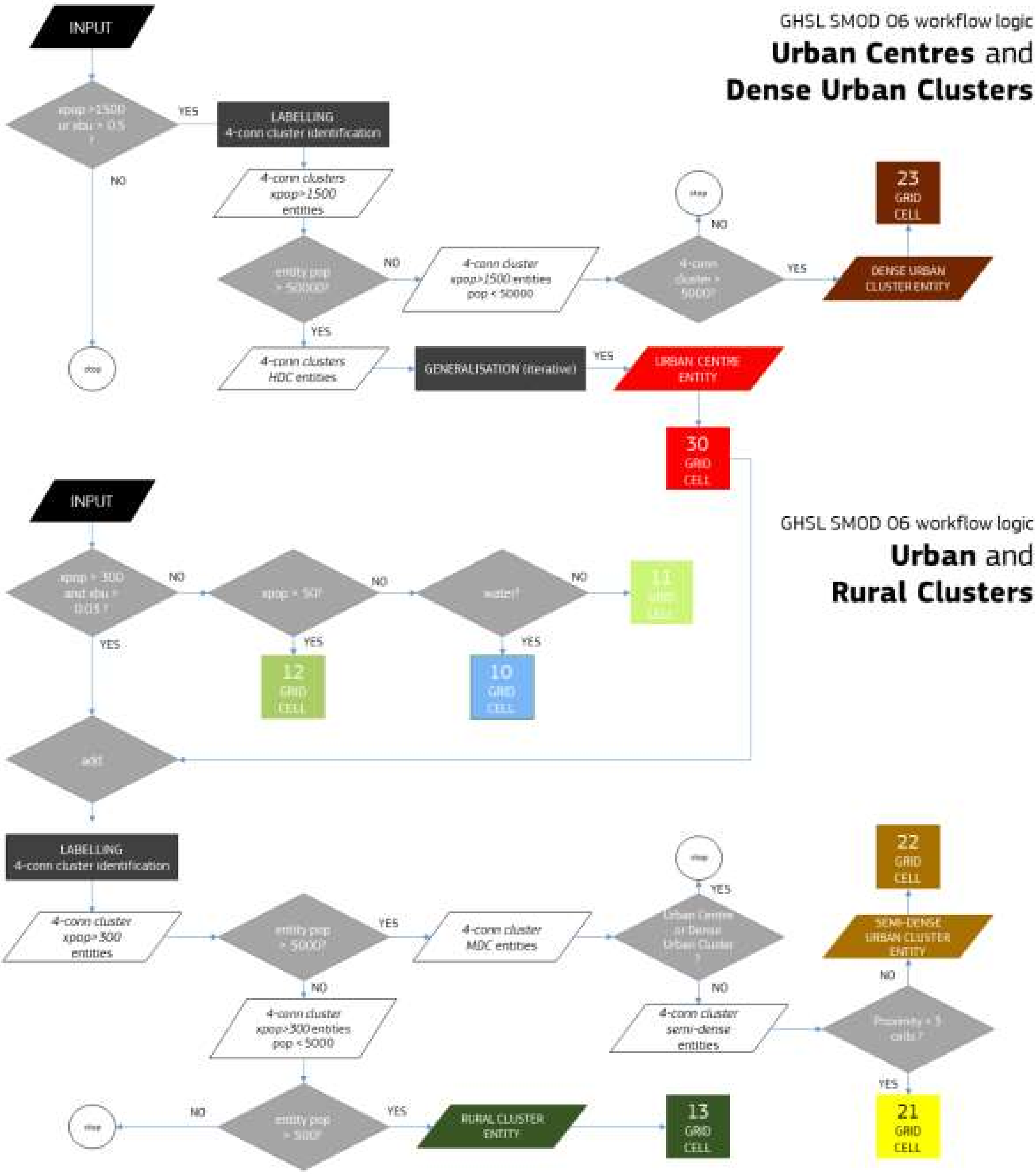

Figure 5. Schematic overview of GHSL SMOD 06 entities workflow logic. “xpop” represents the population density per square kilometre of permanent land; “xbu” represents the built-up density per square kilometre of permanent land.

2.4.5 GHS-SMOD L2 grid and L1 aggregation

Settlement typologies are identified in the GHS-SMOD grid at L2 with a two digit code (30 – 23 – 22 – 21 – 13 – 12 – 11 – 10), linking to grid level and municipal level description terms (both the municipal and grid level terms are accompanied by a technical term). **Classes 30 – 23 – 22 – 21 if aggregated form the “urban domain”, 13 – 12 – 11 – 10 form the “rural domain”**. Table 9 shows the L2 grid cells population (expressed as people per square kilometre: people/km^2) and built-up area (expressed as square kilometres: km^2) expected characteristics in terms of min-max population and built-up density bounds. Table 8 presents the logic to define settlement typologies.

The first level (L1) is obtained by aggregation of L2 according to the first digit of the code, as shown in Table 6 and it represents a porting of the EUROSTAT "degree of urbanization".

Table 6 Aggregation of L2 class typologies to L1 class typologies (EUROSTAT DEGURBA model)

30	→	3
23 – 22 – 21	→	2
13 – 12 – 11 – 10	→	1

L1 classifies three settlement typologies as displayed in Table 10. Settlement typologies are identified at L1 with a single digit code (3 – 2 – 1), and grid level and municipal level terms (both the municipal and grid level are accompanied by a technical term), HDC for type 3, MDC for type 2, and LDC for type 1). Classes 3 - 2 if aggregated form the "urban domain", 1 forms the "rural domain". Table 11 presents the logic to define settlement typologies as described in section 2.4.3. Table 12 shows the L1 grid cells population and built-up area characteristics in terms of min-max population and built-up density bounds.

Table 7 Settlement Model L2 nomenclature

Code	**RGB**	**Grid level term**	**Spatial entity (polygon)** ***Technical term***	**Other cells** ***Technical term***	**Municipal level term** ***Technical term***
30	255 0 0	URBAN CENTRE GRID CELL	URBAN CENTRE *DENSE, LARGE CLUSTER*		CITY *LARGE SETTLEMENT*
23	115 38 0	DENSE URBAN CLUSTER GRID CELL	DENSE URBAN CLUSTER *DENSE, MEDUM CLUSTER*		DENSE TOWN *DENSE, MEDIUM SETTLEMENT*
22	168 112 0	SEMI-DENSE URBAN CLUSTER GRID CELL	SEMI-DENSE URBAN CLUSTER *SEMI-DENSE, MEDIUM CLUSTER*		SEMI-DENSE TOWN *SEMI-DENSE, MEDIUM SETTLEMENT*
21	255 255 0	SUBURBAN OR PERI-URBAN GRID CELL		SUBURBAN OR PERI-URBAN GRID CELLS *SEMI-DEMSE GRID CELLS*	SUBURBAN OR PERI-URBAN AREA *SEMI-DENSE AREA*
13	55 86 35	RURAL CLUSTER GRID CELL	RURAL CLUSTER *SEMI-DENSE, SMALL CLUSTER*		VILLAGE *SMALL SETTLEMENT*
12	171 205 102	LOW DENSITY RURAL GRID CELL		LOW DENSITY RURAL GRID CELLS *LOW DENSITY GRID CELLS*	DISPERSED RURAL AREA *LOW DENSITY AREA*
11	205 245 122	VERY LOW DENSITY RURAL GRID CELL		VERY LOW DENSITY RURAL GRID CELLS *VERY LOW DENSITY GRID CELLS*	MOSTLY UNINHABITED AREA *VERY LOW DENSITY AREA*
10	122 182 245	WATER GRID CELL	-	-	-

Table 8 Settlement Model L2 synthetic explanation of logical definition and grid cell sets

Code	**Logical Definition at 1 km^2 grid cell**	**Grid cell sets used in the logical definition (shares defined on land surface)**			
		P_{dens}: **Local Population Density lower bound ">" (people/km^2)**	**P_{min}:** **Cluster Population lower bound ">" (people)**	**B_{dens}:** **Local share of Built-up Area lower bound ">" (km^2)**	**T_{con}:** **Topological constrains**
30	$(((P_{dens} \vee B_{dens}) \wedge T_{con}) \wedge P_{min}) \vee$ $\vee$ [iterative_median_filter(3-by-3)] $\vee$ [gap_fill(<15km2)][13]	1,500	50,000	0.50	4-connectivity clusters
23	$(((P_{dens} \vee B_{dens}) \wedge T_{con}) \wedge P_{min}) \wedge \neg 30$	1,500	5,000	0.50	4-connectivity clusters
22	$((((P_{dens} \wedge B_{dens}) \wedge T_{con\_1}) \wedge P_{min}) \wedge \neg (30 \vee 23)) \wedge T_{con\_2}$	300	5,000	0.03	1: 4-connectivity clusters; 2: farther than 3km (beyond 3 cells buffer) from 23 or 30
21	$(((((P_{dens} \wedge B_{dens}) \wedge (30 \vee 23)) \wedge T_{con\_1}) \wedge P_{min}) \wedge \neg (30 \vee 23)) \wedge T_{con\_2}$	300	5,000	0.03	1: 4-connectivity clusters; 2: within 3km (within 3 cells buffer) from 23 or 30
13	$((P_{dens} \wedge T_{con}) \wedge P_{min}) \wedge \neg (30 \vee 2X)$	300	500	none	4-connectivity clusters
12	$P_{dens} \wedge \neg (30 \vee 2X \vee 13)$	50	none	none	none
11	$T_{con} \wedge \neg (30 \vee 2X \vee 13 \vee 12)$	none	none	none	On Land (Land>=50% v BU[14]>0% v Pop>0)
10	T_{con}	none	none	none	Not on Land

[13] The seeds for the related spatial entity is obtained before morphological operations
[14] Retaining only contiguous BU at least partially on land.

Table 9 Settlement Model L2 grid cells population and built-up area characteristics (densities on permanent land)

Code	Population		Built-up area	
	Minimum density expected (people/km²)	Minimum density expected (people/km²)	Minimum density expected (share)	Minimum density expected (share)
30	0	∞	0	1
23	0	50,000	0	1
22	300	5,000	0.03	1
21	300	5,000	0.03	1
13	300	5,000	0	1
12	50	500	0	1
11	0	50	0	1
10	0	0	0	0

Table 10 Settlement Model L1 nomenclature

Code	RGB	Grid level term	Spatial entity (polygon) *Technical term*	Other cells *Technical term*	Municipal level term *Technical term*
3	255 0 0	URBAN CENTRE GRID CELL	URBAN CENTRE *HIGH DENSITY CLUSTER (**HDC**)*		CITY *DENSELY POPULATED AREA*
2	255 170 0	URBAN CLUSTER GRID CELL	URBAN CLUSTER *MODERATE DENSITY CLUSTER (**MDC**)*		TOWNS & SEMI-DENSE AREA *INTERMEDIATE DENSITY AREA*
1	115 178 115	RURAL GRID CELL		RURAL GRID CELLS *LOW DENSITY GRID CELL (**LDC**)*	RURAL AREA *THINLY POPULATED AREA*

Table 11 Settlement Model L1 synthetic explanation of logical definition and grid cell sets

Code	Logical Definition at 1 km² grid cell	Grid cell sets used in the logical definition (shares defined on land surface)			
		P_{dens}: Local Population Density lower bound ">" (people/km²)	P_{min}: Cluster Population lower bound ">" (people)	B_{dens}: Local share of Built-up Area lower bound ">" (km²)	T_{con}: Topological constrains
3	$(((P_{dens} \vee B_{dens}) \wedge T_{con}) \wedge P_{min}) \vee$ $\vee$ [iterative_median_filter(3-by-3)] $\vee$ $\vee$ [gap_fill($<15km^2$)] [15]	1,500	50,000	0.50	4-connectivity clusters
2	$(P_{dens} \wedge B_{dens}) \wedge P_{min} \wedge T_{con} \wedge \neg 3$	300	5,000	0.03	4-connectivity clusters
1	$((((P_{dens} \wedge B_{dens}) \wedge 3) \wedge T_{con}) \wedge P_{min}) \wedge$ $\wedge \neg 3^{\S}$	none	none	none	none

[15] The seeds for the related spatial entity is obtained before morphological operations

Table 12 Settlement Model L1 grid cells population and built-up area characteristics (densities on permanent land)

Code	Population		Built-up area	
	Minimum density expected (people/km²)	Minimum density expected (people/km²)	Minimum density expected (share)	Minimum density expected (share)
3	0	∞	0	1
2	0	50,000	0	1
1	0	5,000	0	1

2.4.6 Input Data

The input data are the multi-temporal GHS-BUILT and GHS-POP grids of the GHSL Data Package 2019 (GHS P2019). Land is extracted as a combination of the Global ADMinstrative Map 2.8[16] and the Global Surface Water Layer Occurrence[17]. Names[18] are extracted from OpenStreetMap partially filtered by EUROSTAT (GISCO project[19]).

2.4.7 Technical Details

Author: Martino Pesaresi, Aneta Florczyk, Marcello Schiavina, Luca Maffenini, Michele Melchiorri, Joint Research Centre (JRC) European Commission.

Product name: GHS_SMOD_POP_GLOBE_R2019A

Spatial extent: Global

Temporal extent: 1975-1990-2000-2015

Coordinate System: World Mollweide (EPSG: 54009)

Resolution available: 1 km

Table 13 outlines the technical characteristics of the datasets released in this data package.

2.4.7.1 GHS-SMOD raster grid

Encoding: integer16 [30 – 23 – 22 – 21 – 13 – 12 – 11 – 10], No Data: -200

Data organisation: TIF with CLR colormap (L2_colcod.tif.clr) file as single global layer or tiled.

2.4.7.2 GHS-SMOD Urban Centre entities[20]

Data organisation: GeoPackage (GPKG) database with vector layer of Urban Centre entities boundaries (polygons).

Attributes:

- ID_HDC_G0: Unique Identifiers of the urban centre entity;
- Name_main: Main name assigned to the urban centre entity;
- Name_list: List of all name selected within the spatial entity;
- POP_<year>: sum of GHS-POP within the spatial entity extent for the related year;
- BU_<year>: sum of GHS-BU within the spatial entity extent for the related year

16 https://gadm.org/data.html
17 https://global-surface-water.appspot.com/download
18 Names assigned do not imply official endorsement or acceptance by the European Union © OpenStreetMap
19 https://ec.europa.eu/eurostat/web/gisco
20 This datasets is not comparable with the GHS Urban Centre DataBase v1.x (Florczyk et al., 2019)

Table 13. Technical details of the datasets in GHS_SMOD_POPMT_GLOBE_R2019A

GHS_SMOD_POPMT_GLOBE_R2019A			
ID	**Description**	**Resolution (Projection)**	**Size**
GHS_SMOD_POP2015 _GLOBE_R2019A _54009_1K_V2_0	Settlement typology codes for epoch 2015 NoData [-200]	1 km (World Mollweide)	12 MB
GHS_SMOD_POP2000 _GLOBE_R2019A _54009_1K_V2_0	Settlement typology codes for epoch 2000 NoData [-200]	1 km (World Mollweide)	11.5 MB
GHS_SMOD_POP1990 _GLOBE_R2019A _54009_1K_V2_0	Settlement typology codes for epoch 1990 NoData [-200]	1 km (World Mollweide)	11 MB
GHS_SMOD_POP1975 _GLOBE_R2019A _54009_1K_V2_0	Settlement typology codes for epoch 1975 NoData [-200]	1 km (World Mollweide)	10.5 MB
GHS_SMOD_POP2015 _GLOBE_R2019A _54009_1K_labelHDC_V2_0	2015 Urban Centre entities boundaries	1 km (World Mollweide)	12 MB
GHS_SMOD_POP2000 _GLOBE_R2019A _54009_1K_labelHDC_V2_0	2000 Urban Centre entities boundaries	1 km (World Mollweide)	11.5 MB
GHS_SMOD_POP1990 _GLOBE_R2019A _54009_1K_labelHDC_V2_0	1990 Urban Centre entities boundaries	1 km (World Mollweide)	11 MB
GHS_SMOD_POP1975 _GLOBE_R2019A _54009_1K_labelHDC_V2_0	1975 Urban Centre entities boundaries	1 km (World Mollweide)	10.5 MB

2.4.8 Summary statistics

Table 14 Summary statistics of total area in square kilometres of each settlement typology at global level as obtained from the 1-km GHS-POP grids L2.

	1975	1990	2000	2015
30	306,180	429,229	533,045	665,641
23	207,433	264,360	297,206	331,558
22	111,003	128,511	139,167	154,801
21	421,746	593,198	698,790	823,614
13	818,744	937,466	1,020,680	1,163,761
12	2,832,956	3,221,002	3,558,714	4,024,084
11	140,982,705	140,099,083	139,420,665	138,504,904

Table 15 Summary statistics of total built-up area in square kilometres for each settlement typology at global level as obtained from the 1-km GHS-POP grids L2.

	1975	1990	2000	2015
30	13,023,407	19,163,076	24,892,506	30,005,410
23	4,973,363	6,706,174	7,945,364	8,796,052
22	1,921,714	2,380,061	2,734,640	3,033,187
21	6,270,036	8,940,169	11,002,298	13,449,073
13	4,192,598	5,402,874	6,328,978	7,107,380
12	5,722,583	7,332,990	9,421,017	12,123,285
11	1,851,377	2,407,680	3,249,061	4,423,226

Table 16 Summary statistics of total population in each settlement typology at global level as obtained from the 1-km GHS-POP grids L2.

	1975	1990	2000	2015
30	1,517,602,834	2,211,665,840	2,721,263,070	3,544,107,384
23	847,910,186	1,062,883,725	1,150,518,125	1,246,207,360
22	101,905,977	118,917,179	129,745,641	141,509,191
21	354,038,947	503,932,173	590,913,476	689,211,502
13	714,554,953	825,388,867	891,416,995	1,009,601,490
12	412,707,214	476,210,241	532,137,585	604,474,198
11	112,628,245	110,598,981	110,534,315	114,217,925

Table 17 Summary statistics of total area in square kilometres of each settlement typology at global level as obtained from the 1-km GHS-POP grids L1.

	1975	1990	2000	2015
3	306,180	429,229	533,045	665,641
2	740,182	986,069	1,135,163	1,309,973
2	648,429,638	648,060,702	647,807,792	647,500,386

Table 18 Summary statistics of total built-up area in square kilometres for each settlement typology at global level as obtained from the 1-km GHS-POP grids L1.

	1975	1990	2000	2015
3	13,023,407	19,163,076	24,892,506	30,005,410
2	13,165,112	18,026,405	21,682,301	25,278,312
2	11,766,728	15,143,820	18,999,470	23,654,835

Table 19 Summary statistics of total population in each settlement typology at global level as obtained from the 1-km GHS-POP grids L1.

	1975	1990	2000	2015
3	1,517,602,834	2,211,665,840	2,721,263,070	3,544,107,384
2	1,303,855,109	1,685,733,077	1,871,177,242	2,076,928,054
2	1,239,890,413	1,412,198,089	1,534,088,895	1,728,293,613

2.4.9 How to cite

Dataset:

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) [Dataset] doi:10.2905/42E8BE89-54FF-464E-BE7B-BF9E64DA5218 PID: http://data.europa.eu/89h/42e8be89-54ff-464e-be7b-bf9e64da5218

Concept & Methodology:

Florczyk, Aneta J.; Corbane, Christina; Ehrlich, Daniele; Freire, Sergio; Kemper, Thomas; Maffenini, Luca; Melchiorri, Michele; Pesaresi, Martino; Politis, Panagiotis; Schiavina, Marcello; Sabo, Filip; Zanchetta, Luigi (2019): GHSL Data Package 2019, EUR 29788 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-13187-8 doi: 10.2760/0726, JRC 117104

2.5 GHS Degree of Urbanisation Classification (GHS-DUC), derived from GHS-POP, GHS-BUILT, GHS-SMOD multi-temporal (1975-1990-2000-2015), R2019A and GADM 3.6 [GHS_STAT_DUCMT_GLOBE_R2019A]

The GHS Degree of Urbanisation Classification (GHS-DUC) GHS_STAT_DUCMT_GLOBE_R2019A classifies all GADM 3.6[21] administrative units (from level 0 to level 5) by Degree of Urbanisation class. In total, 386,741 GADM units are classified. This is done according to a logic of majority of population (GHS-POP) in unit overlaid to the settlement classification grid (GHS-SMOD). This classification follows the stage 2 of the application of the Degree of Urbanisation as described by EUROSTAT[22].

In GHS-DUC each GADM polygon (for all available GADM levels) is coded by Degree of Urbanisation Level 1 and Level 2, and has statistics of number of residents and built-up area surface. The GHS-DUC is derived from the GHS-POP (GHS_POP_MT_GLOBE_R2019A, version 1.0) and GHS-SMOD (GHS_SMOD_POPMT_GLOBE_R2019A, version 2.0) to compute population counts per epoch, with additional statistics from GHS-BUILT (GHS_BUILT_LDSMT_GLOBE_R2018A, version 2.0) for computing built-up area values for each epoch.

The GHS Degree of Urbanisation Classification GHS_STAT_DUCMT_GLOBE_R2019A is composed by:

- one summary Excel file collecting results at the finest level available per country for each epoch,
- 24 classification files of all GADM 3.6 units for each level (0-5) and each epoch (1975-1990-2000-2015) released in CSV format.

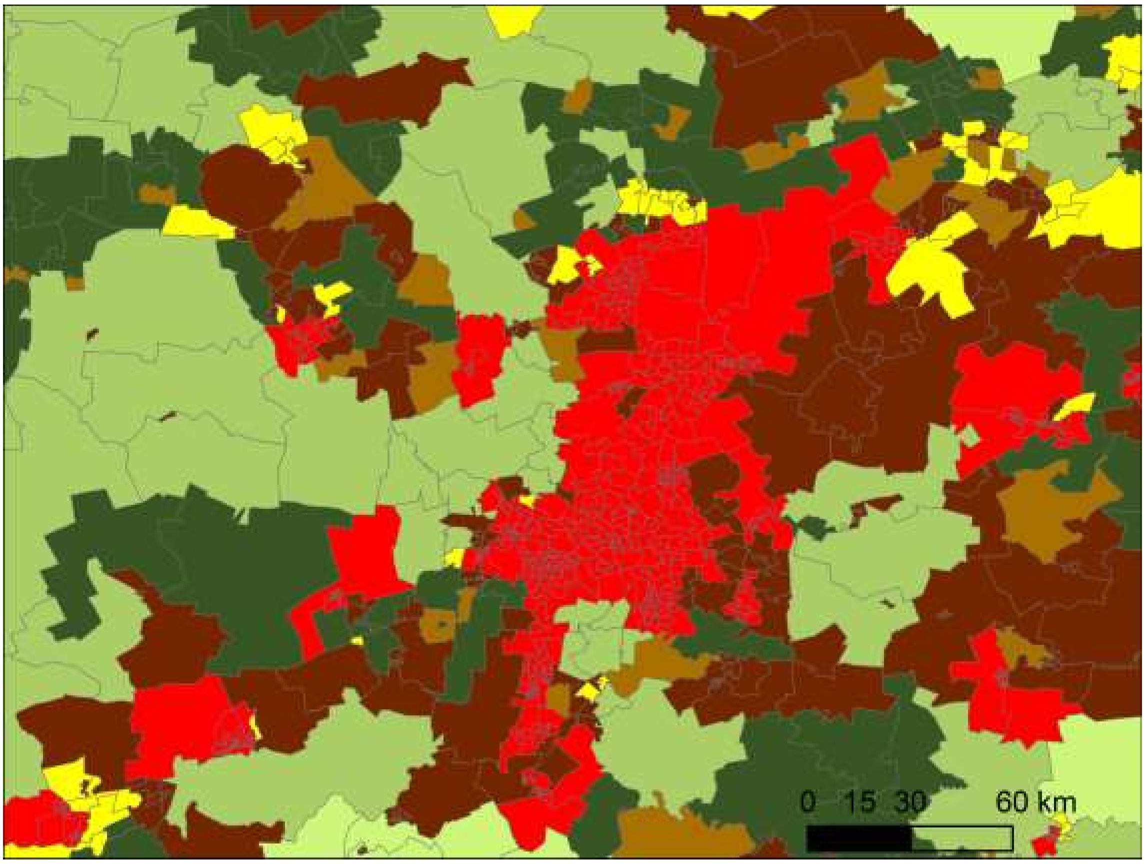

Figure 6 GHS Degree of Urbanisation Classification (GHS-DUC) GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2015_level4 joined to the GADM 3.6 level 4 layer, displayed in the area of Johannesburg and Pretoria (South Africa) showing the classification of local units by Degree of Urbanisation Level 2–Legend in Table 20. The boundaries shown on this map do not imply official endorsement or acceptance by the European Union.

[21] https://gadm.org/index.html

[22] European Commission, and Statistical Office of the European Union, 2021. Applying the Degree of Urbanisation — A methodological manual to define cities, towns and rural areas for international comparisons — 2021 edition Publications Office of the European Union, 2021, ISBN 978-92-76-20306-3 doi: 10.2785/706535

2.5.1 GHSL Territorial Units Classification

The Degree of Urbanisation classifies local units based on population majority applied to the grid level classification. Each local unit is assigned exclusively one DEGURBA class at Level 1 and one at Level 2 (hierarchy based). Local units can be administrative units - such as municipalities - or statistical units - such as census enumeration or reporting areas.

2.5.1.1 Territorial units classification Level 1

Once all grid cells covered by GADM have been classified as urban centres, urban clusters and rural grid cells using the GHS-DUG Tool, the next step concerns overlaying these results onto local units, as follows (Figure 8):

— **Cities (or densely populated areas):** local units that have at least 50% of their population in urban centres, **code 3**.

— **Towns and semi-dense areas (or intermediate density areas):** local units that have less than 50% of their population in urban centres and no more than 50% of their population in rural grid cells, **code 2**.

— **Rural areas (or thinly populated areas):** local units that have more than 50% of their population in rural grid cells, **code 1**.

Urban areas consist of cities plus towns and semi-dense areas.

In some countries, not all the small spatial units contain inhabitants. To classify the spatial units without any population, the same rules should be applied to their area instead of to their population. For example, a small spatial unit without any population that has more than 50 % of its area in rural grid cells is classified as a rural area.

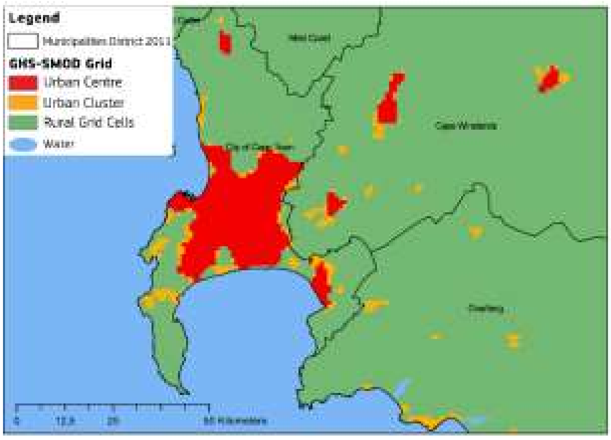

Figure 7 Urban centre, urban cluster and rural grid cells around Cape Town, South Africa

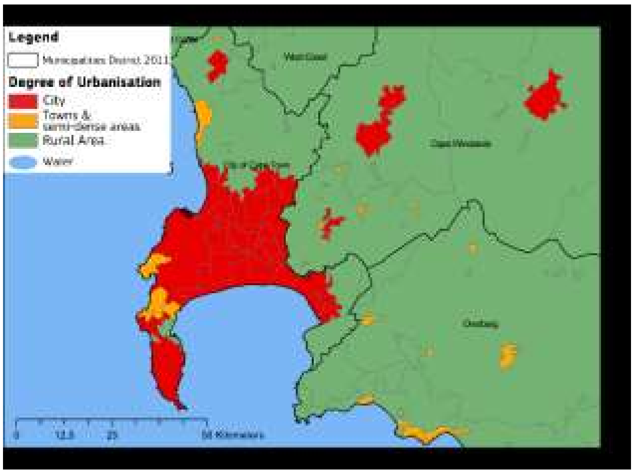

Figure 8 City, towns & semi-dense areas and rural areas around Cape Town, South Africa (classification of Main Places units, note that Cape Peninsula is part of Cape Town Main Place)

2.5.1.2 Territorial units classification Level 2

Local units are classified as cities in identical manner to the Degree of Urbanisation level 1 (Figure 10):

— A city consists of local units that have at least 50% of their population in an urban centre, **code 30**.

Local units classified as “towns and semi-dense areas” can be divided into three classes:

— Dense Towns have a larger share of their population in dense urban clusters than in semi-dense urban clusters (i.e. are dense) and a larger share in dense plus semi-dense urban clusters than in suburban or peri-urban cells (i.e. are towns), **code 23**.

— Semi-dense Towns have a larger population share in semi-dense urban clusters than in dense urban clusters (i.e. are semi-dense) and a larger share in dense plus semi-dense urban clusters than in suburban or peri-urban cells (i.e. are towns), **code 22**.

— Suburban or peri-urban areas have a larger population share in suburban or peri-urban cells than in dense plus semi-dense urban clusters, **code 21**.

Dense and semi-dense towns can be combined into towns. This reduces the number of classes and may be especially useful if the population share in semi-dense towns is low.

Local units classified as “rural areas” can be divided into three classes:

— Villages have the largest share of their rural grid cell population living in a rural cluster, **code 13**.

— Dispersed rural areas have the largest share of their rural grid cell population living in low density rural grid cells, **code 12**.

— Mostly uninhabited areas have the largest share of their rural grid cell population living in very low density rural grid cells, **code 11**.

As for Level 1, to classify the spatial units without any population, the same rules that are applied to population are applied to area.

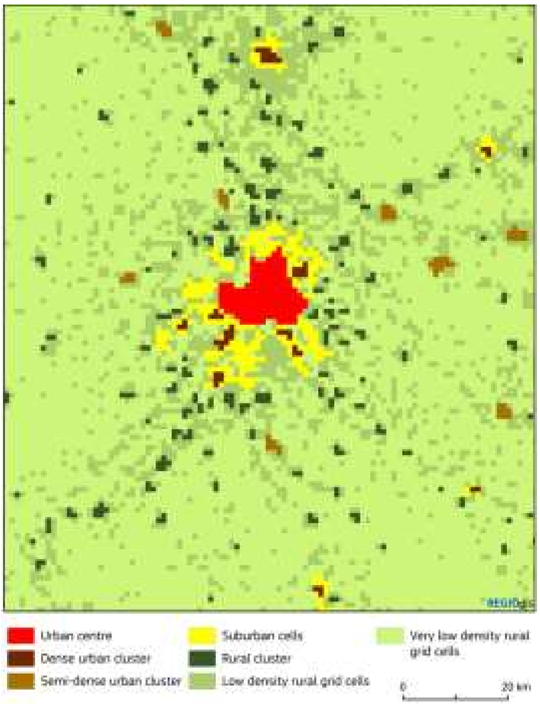

Figure 9 Degree of urbanisation level 2 grid classification around Toulouse, France

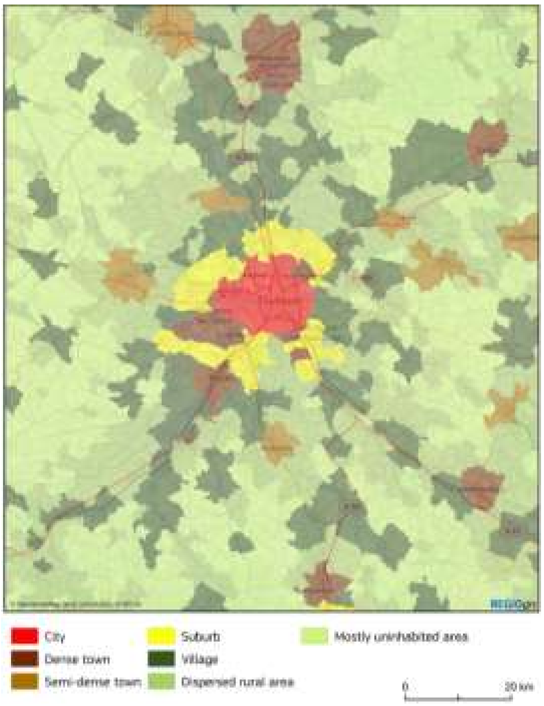

Figure 10 Degree of urbanisation level 2 local unit classification around Toulouse, France

2.5.1.3 *Classification workflow*

The classification has been performed combining three inputs of different nature for each epoch and GADM level:

— two raster layers:

- the settlement classification grid at 1 km for the processed year (GHS-SMOD);
- the population grid at 250m resolution for the same epoch (GHS-POP);

— one vector layer of territorial units from GADM3.6[23] at the processed level.

The procedure begins with the rasterization of the vector layer. As suggested, the unit classification works better with small units, therefore these are rasterized using a resolution of 50 m, snapped to the population grid, to reduce the number of units that will not have a representation in the raster layer. The settlement classification grid (at 1 km resolution) is oversampled using nearest neighbour algorithm to align with the 50-m territorial units' raster. The population grid is also oversampled and the values are then adjusted by dividing all original cells by the oversampling ratio (e.g. from 250 m to 50 m the ratio is 25, as 25 grid cells of 50 m compose each 250 m cell) assuming a uniform distribution of population within each cell.

Once the pre-processing of the layers is completed, the algorithm computes for each unit the share of population in each class of the settlement classification grid (both at Level 1 and 2), through zonal statistics, and assigns the class of the unit accordingly (i.e. following the classification rules described in sections 2.5.1.1 and 2.5.1.2). When a unit is unpopulated it runs zonal statistics of areas per settlement classification.

Even if the working resolution is set at 50 m, it could happen that some small polygons could not be rasterised due to geospatial data processing constrains. In such cases the algorithm evaluates the class of these polygons by running separately the zonal statistics (i.e. one polygon at a time) and performing the rasterization procedure with "all touching cells" option. To avoid double counting of population, no population is assigned to such polygons, but the classification still considers population per class in the rasterised cells.

2.6 A consistent nomenclature for the Degree of Urbanisation

Two sets of terms have been developed to describe each of the classes of the Degree of Urbanisation (Table 20, Table 21). The first set uses simple and short terms such as city, town, suburb and village. The second set uses a more neutral and technical language. The second set can be helpful to avoid overlap with the terms used in the national definition.

Table 20 Territorial Units classification L2 nomenclature

Code	**RGB**	**Municipal level term** ***Technical term***
30	255 0 0	CITY *LARGE SETTLEMENT*
23	115 38 0	DENSE TOWN *DENSE, MEDIUM SETTLEMENT*
22	168 112 0	SEMI-DENSE TOWN *SEMI-DENSE, MEDIUM SETTLEMENT*
21	255 255 0	SUBURBS OR PERI-URBAN AREA *SEMI-DENSE AREA*
13	55 86 35	VILLAGE *SMALL SETTLEMENT*
12	171 205 102	DISPERSED RURAL AREA *LOW DENSITY AREA*
11	205 245 122	MOSTLY UNINHABITED AREA *VERY LOW DENSITY AREA*

[23] https://gadm.org/download_world.html

Table 21 Territorial Units classification L1 nomenclature

Code	RGB	Municipal level term ***Technical term***
3	255 0 0	CITY *DENSELY POPULATED AREA*
2	255 170 0	TOWNS & SEMI-DENSE AREA *INTERMEDIATE DENSITY AREA*
1	115 178 115	RURAL AREA *THINLY POPULATED AREA*

2.6.1 How to use the statistics tables

The classification of territorial units by Degree of Urbanisation has two principal objectives. Primarily to relate available statistics (e.g. Demographic and Health Surveys, statistics on labour, housing, etc.) to a DEGURBA classification (e.g. urban/rural). Second, to account urban and rural populations for administrative areas. Both applications would harmonise nationally collected statistics to a common urban and rural classification of territorial units, useful for international statistical comparison as recommended by the United Nations Statistical Commission.

To relate available national statistics to the corresponding GHS-DUC level, it is important to verify in the mapping table Table 22 the relation between the territorial unit for which the statistic is available and the corresponding GADM level. Once the territorial designation in the statistic matches a GADM level, the statistic can be coded by Degree of Urbanisation joining or relating each field in the statistics table, to the GADM level classification of the units by Degree of Urbanisation with the GHS-DUC field 'DEGURBA_L1' or 'DEGURBA_L2'. This operation can be conducted using any of the GHS-DUC tables GHS_STAT_DUCMT_GLOBE_R2019A_v1_0_GADM36_*<year>*_level*X*, where *<year>* correspond to the epoch, and *X* to the GADM Level in the specific table. To account urban and rural populations for administrative areas by Degree of Urbanisation the user can refer to the product GHS_STAT_DUCMT_GLOBE_R2019A_v1_0.xlsx. The table lists for all GADM countries and territories, the population per unit by Degree of Urbanisation class and the corresponding share for the finest GADM level. The table includes aggregated statistics at global level also available per epoch.

The epoch refers to the underlying GHS-POP and GHS-SMOD epoch used, keeping the GADM geometry fixed (version 3.6.).

2.6.2 Input Data

The input data are the multi-temporal GHS-SMOD, GHS-POP and GHS-BUILT grids of the GHSL Data Package 2019 (GHS P2019). Territorial units are the Global ADMinstrative Map 3.6[24]

[24] https://gadm.org/data.html

2.6.3 Technical Details

Author: Marcello Schiavina, Michele Melchiorri, Sergio Freire Joint Research Centre (JRC) European Commission.

Product name: GHS_STAT_DUCMT_GLOBE_R2019A

Spatial extent: Global

Temporal extent: 1975-1990-2000-2015

2.6.3.1 GHS-DUC Summary Statistics Table

Data organisation: XLSX with Global statistics of Population per class for each epoch, and sheets per epoch showing Territory or Country statistics of classification at the finest GADM level available.

Territory or Country statistics sheet attributes:

- GADM code: Numerical ID of territory in GADM
- GADM ISO: ISO code of territory in GADM
- GADM NAME: Territory name in GADM
- Selected GADM Level: Finest available GADM level for territory
- GADM level type: Description of the selected level according to GADM attribute "ENGTYPE" for the level (When GADM entry is missing description "N/A" is reported)
- Total Units: Total Territory units at selected GADM level
- Total Area km2: Total Area of the territory in km2
- Average Area km2: Average unit size of the territory at selected GADM level
- Share of Urban Population: Share of population in administrative units classified as Urban (Cities, Towns and Suburbs)
- DEGURBA L1 Population
  - Rural Area: Population of units classified as Rural Areas in Degree of Urbanisation level 1
  - Town & Semi-Dense area: Population of units classified as Town & Suburbs in Degree of Urbanisation level 1
  - City: Population of units classified as Cities in Degree of Urbanisation level 1
- DEGURBA L2 Population
  - Mostly uninhabited area: Population of units classified as Mostly uninhabited Areas in Degree of Urbanisation level 2
  - Rural dispersed area: Population of units classified as Rural dispersed Areas in Degree of Urbanisation level 2
  - Village: Population of units classified as Villages in Degree of Urbanisation level 2
  - Suburban or peri-urban area: Population of units classified as Suburbs or peri-urban areas in Degree of Urbanisation level 2
  - Semi-dense Town: Population of units classified as Semi-dense Towns in Degree of Urbanisation level 2
  - Dense Town: Population of units classified as Dense Towns in Degree of Urbanisation level 2
  - City: Population of units classified as Cities in Degree of Urbanisation level 2
- Total Pop: Total Territory population
- DEGURBA L1 Units
  - Rural Area: Number of units classified as Rural Areas in Degree of Urbanisation level 1

- Town & Semi-Dense area: Number of units classified as Town & Suburbs in Degree of Urbanisation level 1
- City: Number of units classified as Cities in Degree of Urbanisation level 1

- DEGURBA L2 Units
  - Mostly uninhabited area: Number of units classified as Mostly uninhabited Areas in Degree of Urbanisation level 2
  - Rural dispersed area: Number of units classified as Rural dispersed Areas in Degree of Urbanisation level 2
  - Village: Number of units classified as Villages in Degree of Urbanisation level 2
  - Suburban or peri-urban area: Number of units classified as Suburbs or peri-urban areas in Degree of Urbanisation level 2
  - Semi-dense Town: Number of units classified as Semi-dense Towns in Degree of Urbanisation level 2
  - Dense Town: Number of units classified as Dense Towns in Degree of Urbanisation level 2
  - City: Number of units classified as Cities in Degree of Urbanisation level 2

2.6.3.2 GHS-DUC Admin Classification layers

Data organisation: CSV files to be joined to the original GADM3.6 layer at the respective level.

Attributes:

- GID_<level>: GADM 3.6 ID at current level [join filed with GADM layer at respective level]
- GID_0: GADM 3.6 ID at country or territory level0
- Tot_Pop: Total population
- UCentre_Pop: Urban Centre population
- UCluster_Pop: Urban Cluster population
- Rural_Pop: Rural Population
- UCentre_share: Share of Urban Centre Population
- UCluster_share: Share of Urban Cluster population
- Urban_share: Share of Urban Population (Urban Centre + Urban Cluster)
- Rural_share: Share of Rural Population
- DEGURBA_L1: Classification according to Degree of Urbanisation level 1
- DUC_Pop: Dense Urban Cluster Population
- SDUC_Pop: Semi-dense Urban Cluster Population
- SUrb_Pop: Suburban and peri-urban grid cells Population
- RC_Pop: Rural Cluster Population
- LDR_Pop: Low Density Rural grid cells Population
- VLDR_Pop: Very Low Density Rural grid cells Population
- DUC_share: Share of Dense Urban Cluster Population
- SDUC_share: Share of Semi-dense Urban Cluster Population
- SUrb_share: Share of Suburban and peri-urban grid cells Population
- RC_share: Share of Rural Cluster Population

- LDR_share: Share of Low Density Rural grid cells Population
- VLDR_share: Share of Very Low Density Rural grid cells Population
- DEGURBA_L2: Classification according to Degree of Urbanisation level 2
- BU_km2: Built-up area in km2

Classified GADM level types per country or territory: see Table 22

Table 23 outlines the technical characteristics of the datasets released in this data package.

Table 22 *GADM level type per country or territory (level 0 omitted as representing the full country or territory)*

GADM ISO	GADM NAME	Level 1	Level 2	Level 3	Level 4	Level 5
AFG	Afghanistan	Province	District	-	-	-
XAD	Akrotiri and Dhekelia	Sovereign Base Area	-	-	-	-
ALA	Åland	Municipality	-	-	-	-
ALB	Albania	County	District	Bashkia	-	-
DZA	Algeria	Province	Chef-Lieu-Wilaya	-	-	-
ASM	American Samoa	District	County	Village	-	-
AND	Andorra	Parish	-	-	-	-
AGO	Angola	Province	Municpality|City Council	Commune	-	-
AIA	Anguilla	-	-	-	-	-
ATA	Antarctica	-	-	-	-	-
ATG	Antigua and Barbuda	Dependency	-	-	-	-
ARG	Argentina	Province	Part	-	-	-
ARM	Armenia	Province	-	-	-	-
ABW	Aruba	-	-	-	-	-
AUS	Australia	Territory	Territory	-	-	-
AUT	Austria	State	Statutory City	Municipality	-	-
AZE	Azerbaijan	Region	District	-	-	-
BHS	Bahamas	District	-	-	-	-
BHR	Bahrain	Governorate	-	-	-	-
BGD	Bangladesh	Division	Distict	Upazilla	Union	-
BRB	Barbados	Parish	-	-	-	-
BLR	Belarus	Region	District	-	-	-
BEL	Belgium	Region	Capital Region	Arrondissement	Commune	-
BLZ	Belize	District	-	-	-	-
BEN	Benin	Department	Commune	-	-	-
BMU	Bermuda	Parish	-	-	-	-
BTN	Bhutan	District	Village block	-	-	-
BOL	Bolivia	Department	Province	Municipality	-	-
BES	Bonaire, Sint Eustatius and Saba	Municipality	-	-	-	-
BIH	Bosnia and Herzegovina	District	N/A	Commune	-	-
BWA	Botswana	District	Sub-district	-	-	-
BVT	Bouvet Island	-	-	-	-	-
BRA	Brazil	State	Municipality	District	-	-
IOT	British Indian Ocean Territory	-	-	-	-	-
VGB	British Virgin Islands	District	-	-	-	-
BRN	Brunei	District	Mukim	-	-	-
BGR	Bulgaria	Province	Municipality	-	-	-
BFA	Burkina Faso	Region	Province	Department	-	-
BDI	Burundi	Province	Commune	Colline	Sous Colline	-
KHM	Cambodia	Province	District	Commune	Village	-
CMR	Cameroon	Region	Department	Arrondissement	-	-
CAN	Canada	Province	Census Division	Town	-	-
CPV	Cape Verde	County	-	-	-	-
XCA	Caspian Sea	-	-	-	-	-
CYM	Cayman Islands	District	-	-	-	-
CAF	Central African Republic	Prefecture	Sub-prefecture	-	-	-
TCD	Chad	Region	Department	Sub-prefecture	-	-
CHL	Chile	Region	Province	Municipality	-	-
CHN	China	Province	Prefecture City	County City	-	-

CXR	Christmas Island	-	-	-	-	-
XCL	Clipperton Island	-	-	-	-	-
CCK	Cocos Islands	-	-	-	-	-
COL	Colombia	Commissiary	Corregimiento Departamento	-	-	-
COM	Comoros	Autonomous Island	-	-	-	-
COK	Cook Islands	-	-	-	-	-
CRI	Costa Rica	Province	Canton	-	-	-
CIV	Côte d'Ivoire	Autonomous district	Autonomous district	Department	Sub-prefecture	-
HRV	Croatia	County	N/A	-	-	-
CUB	Cuba	Province	Municipality	-	-	-
CUW	Curaçao	-	-	-	-	-
CYP	Cyprus	District	-	-	-	-
CZE	Czech Republic	Region	District	-	-	-
COD	Democratic Republic of the Congo	Province	Territory	-	-	-
DNK	Denmark	Region	Municipality	-	-	-
DJI	Djibouti	Region	District	-	-	-
DMA	Dominica	Parish	-	-	-	-
DOM	Dominican Republic	Province	Municipality	-	-	-
ECU	Ecuador	Province	Canton	Cantonal Head	-	-
EGY	Egypt	Governorate	Subdivision	-	-	-
SLV	El Salvador	Department	Municipality	-	-	-
GNQ	Equatorial Guinea	Province	Districts | Municipals	-	-	-
ERI	Eritrea	Region	District	-	-	-
EST	Estonia	County	Parish	Town	-	-
ETH	Ethiopia	City	Zone	District	-	-
FLK	Falkland Islands	-	-	-	-	-
FRO	Faroe Islands	Region	Commune	-	-	-
FJI	Fiji	Division	Province	-	-	-
FIN	Finland	Province	Region	Sub-Region	Municipality	-
FRA	France	Region	Department	Districts	Cantons	Commune
GUF	French Guiana	Arrondissement	Commune	-	-	-
PYF	French Polynesia	Administrative subdivisions	-	-	-	-
ATF	French Southern Territories	District	-	-	-	-
GAB	Gabon	Province	Department	-	-	-
GMB	Gambia	Independent City	District	-	-	-
GEO	Georgia	Autonomous Republic	District	-	-	-
DEU	Germany	State	District	Municipality	Town	-
GHA	Ghana	Region	District	-	-	-
GIB	Gibraltar	-	-	-	-	-
GRC	Greece	Decentralized administration	Region	Municipality	-	-
GRL	Greenland	Commune	-	-	-	-
GRD	Grenada	Dependency	-	-	-	-
GLP	Guadeloupe	District	Commune	-	-	-
GUM	Guam	Municipality	-	-	-	-
GTM	Guatemala	Department	Municipality	-	-	-
GGY	Guernsey	Parish	-	-	-	-
GIN	Guinea	Region	Prefecture	Sub-prefecture	-	-
GNB	Guinea-Bissau	Region	Sector	-	-	-
GUY	Guyana	Region	Not Classified	-	-	-
HTI	Haiti	Department	District	Commune	Sub-commune	-
HMD	Heard Island and McDonald Islands	-	-	-	-	-
HND	Honduras	Department	Municipality	-	-	-
HKG	Hong Kong	District	-	-	-	-
HUN	Hungary	County	Subregion	-	-	-
ISL	Iceland	Region	Municipality	-	-	-
IND	India	Union Territory	District	Taluk	-	-
IDN	Indonesia	Province	Regency	Sub-district	Village	-
IRN	Iran	Province	County	-	-	-
IRQ	Iraq	Province	N/A	-	-	-
IRL	Ireland	County	-	-	-	-
IMN	Isle of Man	N/A	N/A	-	-	-
ISR	Israel	District	-	-	-	-

ITA	Italy	Region	Province	Commune	-	-
JAM	Jamaica	Parish	-	-	-	-
JPN	Japan	Prefecture	Town	-	-	-
JEY	Jersey	Parish	-	-	-	-
JOR	Jordan	Province	Sub-Province	-	-	-
KAZ	Kazakhstan	Region	District	-	-	-
KEN	Kenya	County	Constituency	Ward	-	-
KIR	Kiribati	-	-	-	-	-
XKO	Kosovo	District	Town | Municipal	-	-	-
KWT	Kuwait	Province	-	-	-	-
KGZ	Kyrgyzstan	Province	District	-	-	-
LAO	Laos	Province	District	-	-	-
LVA	Latvia	Province	District	-	-	-
LBN	Lebanon	Governorate	District	Municipality	-	-
LSO	Lesotho	District	-	-	-	-
LBR	Liberia	County	District	Clan	-	-
LBY	Libya	District	-	-	-	-
LIE	Liechtenstein	Commune	-	-	-	-
LTU	Lithuania	County	District Municipality	-	-	-
LUX	Luxembourg	District	Canton	Commune	Commune (same as level 3)	-
MAC	Macao	District	Parish	-	-	-
MKD	Macedonia	Municipality	-	-	-	-
MDG	Madagascar	Autonomous Province	Region	District	Commune	-
MWI	Malawi	District	Town	Unknown	-	-
MYS	Malaysia	State	District	-	-	-
MDV	Maldives	-	-	-	-	-
MLI	Mali	District	Circle	Arrondissement	Commune	-
MLT	Malta	Region	Local council	-	-	-
MHL	Marshall Islands	-	-	-	-	-
MTQ	Martinique	Arrondissement	Commune	-	-	-
MRT	Mauritania	Region	Department	-	-	-
MUS	Mauritius	Region	-	-	-	-
MYT	Mayotte	Commune	-	-	-	-
MEX	Mexico	State	Municipality	-	-	-
FSM	Micronesia	State	-	-	-	-
MDA	Moldova	District	-	-	-	-
MCO	Monaco	-	-	-	-	-
MNG	Mongolia	Province	Sum	-	-	-
MNE	Montenegro	Municipality	-	-	-	-
MSR	Montserrat	Parish	-	-	-	-
MAR	Morocco	Region	Province	District	Rural Commune	-
MOZ	Mozambique	Province	District	Locality	-	-
MMR	Myanmar	Division	District	Village | Township	-	-
NAM	Namibia	Region	Constituency	-	-	-
NRU	Nauru	District	-	-	-	-
NPL	Nepal	Development Region	Administrative Zone	District	Village development committee	-
NLD	Netherlands	Province	Municipality	-	-	-
NCL	New Caledonia	Province	Commune	-	-	-
NZL	New Zealand	Region	District	-	-	-
NIC	Nicaragua	Autonomous Region	Municipality	-	-	-
NER	Niger	Department	Arrondissement	Commune	-	-
NGA	Nigeria	State	Local Authority	-	-	-
NIU	Niue	-	-	-	-	-
NFK	Norfolk Island	-	-	-	-	-
PRK	North Korea	Province	County	-	-	-
XNC	Northern Cyprus	District	-	-	-	-
MNP	Northern Mariana Islands	Municipality	-	-	-	-
NOR	Norway	County	Municipality	-	-	-
OMN	Oman	Region	Province	-	-	-
PAK	Pakistan	Centrally Administered Area	Division	District	-	-
PLW	Palau	State	-	-	-	-
PSE	Palestina	District	Governorate	-	-	-
PAN	Panama	Province	District	Municipality	-	-
PNG	Papua New Guinea	Autonomous Region	District	-	-	-

XPI	Paracel Islands	-	-	-	-	-
PRY	Paraguay	Department	District	-	-	-
PER	Peru	Region	Province	District	-	-
PHL	Philippines	Province	Municipality	Village	-	-
PCN	Pitcairn Islands	-	-	-	-	-
POL	Poland	Province |Voivodeship	County	Municipality (urban)	-	-
PRT	Portugal	District	Municipality	Parish	-	-
PRI	Puerto Rico	Municipality	-	-	-	-
QAT	Qatar	Municipality	-	-	-	-
COG	Republic of Congo	Region	District	-	-	-
REU	Reunion	Arrondissement	Commune	-	-	-
ROU	Romania	County	Commune	-	-	-
RUS	Russia	Republic	District	N/A	-	-
RWA	Rwanda	Province	District	Sector	Cell	Village
BLM	Saint-Barthélemy	-	-	-	-	-
MAF	Saint-Martin	-	-	-	-	-
SHN	Saint Helena	Administrative Area	Administrative Area	-	-	-
KNA	Saint Kitts and Nevis	Parish	-	-	-	-
LCA	Saint Lucia	Quarter	-	-	-	-
SPM	Saint Pierre and Miquelon	Commune	-	-	-	-
VCT	Saint Vincent and the Grenadines	Parish	-	-	-	-
WSM	Samoa	District	Unknown	-	-	-
SMR	San Marino	Municipality	-	-	-	-
STP	São Tomé and Príncipe	Municipality	N/A	-	-	-
SAU	Saudi Arabia	Region	-	-	-	-
SEN	Senegal	Region	Department	Arrondissement	Commune	-
SRB	Serbia	District	Town|Municipal	-	-	-
SYC	Seychelles	District	-	-	-	-
SLE	Sierra Leone	Province	District	Chiefdom	-	-
SGP	Singapore	Region	-	-	-	-
SXM	Sint Maarten	-	-	-	-	-
SVK	Slovakia	Region	District	-	-	-
SVN	Slovenia	Statistical Region	Commune | Municipality	-	-	-
SLB	Solomon Islands	Province	Ward	-	-	-
SOM	Somalia	Region	District	-	-	-
ZAF	South Africa	Province	District Municipality	Local Municipality	Ward	-
SGS	South Georgia and the South Sandwich Islands	-	-	-	-	-
KOR	South Korea	Metropolitan City	District	-	-	-
SSD	South Sudan	State	District	Unknown	-	-
ESP	Spain	Autonomous Community	Province	Comarca	Municipality	-
XSP	Spratly Islands	-	-	-	-	-
LKA	Sri Lanka	District	Division	-	-	-
SDN	Sudan	State	District	Unknown	-	-
SUR	Suriname	District	Ressort	-	-	-
SJM	Svalbard and Jan Mayen	Territory	-	-	-	-
SWZ	Swaziland	District	Constituency	-	-	-
SWE	Sweden	County	Municipality	-	-	-
CHE	Switzerland	Canton	District	Municipality	-	-
SYR	Syria	Province	District	-	-	-
TWN	Taiwan	Province	County	-	-	-
TJK	Tajikistan	Region	N/A	N/A	-	-
TZA	Tanzania	Region	District	Ward	-	-
THA	Thailand	Province	District	Sub district	-	-
TLS	Timor-Leste	District	Subdistrict	Community	-	-
TGO	Togo	Region	Prefecture	-	-	-
TKL	Tokelau	Atoll	-	-	-	-
TON	Tonga	Island Group	-	-	-	-
TTO	Trinidad and Tobago	Borough	-	-	-	-
TUN	Tunisia	Governorate	Delegation	-	-	-
TUR	Turkey	Province	District	-	-	-
TKM	Turkmenistan	Province	-	-	-	-

TCA	Turks and Caicos Islands	District	-	-	-	-
TUV	Tuvalu	Town Council	-	-	-	-
UGA	Uganda	District	County	Sub-county	Parish	-
UKR	Ukraine	Region	Mis'ka Rada	-	-	-
ARE	United Arab Emirates	Emirate	Municipal Region	Municipality	-	-
GBR	United Kingdom	Kingdom	Metropolitan Borough	Metropolitan borough	-	-
USA	United States	State	County	-	-	-
UMI	United States Minor Outlying Islands	Island	-	-	-	-
URY	Uruguay	Department	Poblacion	-	-	-
UZB	Uzbekistan	Region	District	-	-	-
VUT	Vanuatu	Province	Area council	-	-	-
VAT	Vatican City	-	-	-	-	-
VEN	Venezuela	State	Municipality	-	-	-
VNM	Vietnam	Province	District	Townlet	-	-
VIR	Virgin Islands, U.S.	District	N/A	-	-	-
WLF	Wallis and Futuna	Kingdom	District	-	-	-
ESH	Western Sahara	Province	-	-	-	-
YEM	Yemen	Governorate	District	-	-	-
ZMB	Zambia	Province	District	-	-	-
ZWE	Zimbabwe	City	District	-	-	-

Table 23. Technical details of the datasets in GHS_STAT_DUCMT_GLOBE_R2019A

GHS_STAT_DUCMT_GLOBE_R2019A		
ID	**Description**	**Size**
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0	Global Degree of Urbanisation by epoch	0.3 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2015_level0	Degree of Urbanisation of GADM36 level 0 units in 2015	0.1 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2015_level1	Degree of Urbanisation of GADM36 level 1 units in 2015	1 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2015_level2	Degree of Urbanisation of GADM36 level 2 units in 2015	9 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2015_level3	Degree of Urbanisation of GADM36 level 3 units in 2015	23 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2015_level4	Degree of Urbanisation of GADM36 level 4 units in 2015	19 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2015_level5	Degree of Urbanisation of GADM36 level 5 units in 2015	7 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2000_level0	Degree of Urbanisation of GADM36 level 0 units in 2000	0.1 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2000_level1	Degree of Urbanisation of GADM36 level 1 units in 2000	1 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2000_level2	Degree of Urbanisation of GADM36 level 2 units in 2000	9 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2000_level3	Degree of Urbanisation of GADM36 level 3 units in 2000	23 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2000_level4	Degree of Urbanisation of GADM36 level 4 units in 2000	19 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_2000_level5	Degree of Urbanisation of GADM36 level 5 units in 2000	7 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_1990_level0	Degree of Urbanisation of GADM36 level 0 units in 1990	0.1 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_1990_level1	Degree of Urbanisation of GADM36 level 1 units in 1990	1 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_1990_level2	Degree of Urbanisation of GADM36 level 2 units in 1990	9 MB

GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_1990_level3	Degree of Urbanisation of GADM36 level 3 units in 1990	23 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_1990_level4	Degree of Urbanisation of GADM36 level 4 units in 1990	19 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_1990_level5	Degree of Urbanisation of GADM36 level 5 units in 1990	7 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_1975_level0	Degree of Urbanisation of GADM36 level 0 units in 1975	0.1 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_1975_level1	Degree of Urbanisation of GADM36 level 1 units in 1975	1 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_1975_level2	Degree of Urbanisation of GADM36 level 2 units in 1975	9 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_1975_level3	Degree of Urbanisation of GADM36 level 3 units in 1975	23 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_1975_level4	Degree of Urbanisation of GADM36 level 4 units in 1975	19 MB
GHS_STAT_DUCMT_GLOBE_R2019A_V1_0_GADM36_1975_level5	Degree of Urbanisation of GADM36 level 5 units in 1975	7 MB

2.6.4 Summary statistics

Table 24 Summary statistics of total population in each administrative classification typology at global level as obtained from the 1-km GHS-SMOD grids L1 and L2 and GHS-POP 250m.

		GLOBAL DEGURBA							
		1975		1990		2000		2015	
Urban Population		3,122,745,897	77.0%	4,356,476,105	82.2%	5,133,814,113	83.9%	6,257,543,995	85.3%
DEGURBAL1	**City**	1,494,263,908	36.9%	2,195,759,668	41.4%	2,744,304,060	44.9%	3,621,332,332	49.4%
	Town & Semi Dense areas	1,628,481,989	40.2%	2,160,716,437	40.8%	2,389,510,053	39.1%	2,636,211,663	35.9%
	Rural Area	931,575,866	23.0%	944,346,971	17.8%	982,797,348	16.1%	1,080,155,351	14.7%
DEGURBAL2	**City**	1,494,590,975	36.9%	2,195,759,668	41.4%	2,744,304,060	44.9%	3,621,332,332	49.4%
	Dense Town	1,366,427,445	33.7%	1,791,269,880	33.8%	1,984,371,179	32.4%	2,176,159,338	29.7%
	Semi-dense Town	131,045,157	3.2%	160,980,675	3.0%	165,030,045	2.7%	183,368,596	2.5%
	Suburban or peri-urban area	131,260,743	3.2%	208,465,882	3.9%	240,108,829	3.9%	276,683,729	3.8%
	Village	621,961,995	15.3%	639,869,882	12.1%	655,757,454	10.7%	712,419,865	9.7%
	Rural dispersed area	246,145,809	6.1%	251,531,530	4.7%	281,619,436	4.6%	326,013,295	4.4%
	Mostly uninhabited area	63,468,062	1.6%	52,945,559	1.0%	45,420,458	0.7%	41,722,192	0.6%

2.6.5 How to cite

Dataset:

Schiavina, Marcello, Melchiorri, Michele and Freire, Sergio. 2021. GHS_STAT_DUC R2019A - GHS Degree of Urbanisation Classification (2015, 2000, 1990, 1975), R2019A. European Commission, Joint Research Centre (JRC) [Dataset] DOI:10.2905/ED8E8E11-62C3-4895-A7B9-5EF851F112ED PID: http://data.europa.eu/89h/ed8e8e11-62c3-4895-a7b9-5ef851f112ed

Concept & Methodology:

European Commission, and Statistical Office of the European Union, 2021. Applying the Degree of Urbanisation — A methodological manual to define cities, towns and rural areas for international comparisons — 2021 edition Publications Office of the European Union, 2021, ISBN 978-92-76-20306-3 doi:10.2785/706535

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