WORKING GROUP ON DATA INTEGRATION

The integration of geospatial data and statistics to compute SDG indicators: requirements and practices

UN-GGIM: EUROPE

UNITED NATIONS COMMITTEE OF EXPERTS ON GLOBAL GEOSPATIAL INFORMATION MANAGEMENT

Guidelines for SDG Indicator Calculation

11 SUSTAINABLE CITIES AND COMMUNITIES

11.3.1 Land consumption rate to population growth rate

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A. INDICATOR CALCULATION AND DISCUSSION

1. DEFINITION

This indicator is used to monitor the progress towards SDG 11 on making cities and human settlements inclusive, safe, resilient, and sustainable. This includes enhancing inclusive and sustainable urbanization and capacity for participatory, integrated, and sustainable human settlement planning and management in all countries.

At global level, the indicator is defined as the ratio of land consumption rate to population growth rate.

The indicator calculation requires the computation of two components defined at the global level as[1]:

1) Land consumption is the uptake of land by urbanized land uses, which often involves conversion of land from non-urban to urban functions. Land consumption rate is the rate at which urbanized land or land occupied by city / urban area changes during a period of time (usually one year), expressed as a percentage of the land occupied by the city/urban area at the start of that time". Built-up area is defined as all areas occupied by buildings.
2) Population growth is the change of a population in a defined area (country, city, etc.) during a period, usually one year, expressed as a percentage of the population at the start of that period. It reflects the number of births and deaths during a period and the number of people migrating to and from the area defined as urban/city.

Both components indicate a change within a certain period and in a given spatial reference unit, where the period observed must be equal for both components. The indicator also requires the definition of city or urban area and, at the global level, the Degree of Urbanisation (DEGURBA)[2] is proposed to be used to delineate cities or urban areas.

The global metadata also identifies two important secondary indicators which help interpret the value of the main indicator based on the same input data:

- Built-up area per capita which is a measure of the average amount of built-up area available to each person in an urban area during each analysis year. This indicator can help identify when urban areas become too dense and/or when they become too sparsely populated.
- Total change in built-up area which is a measure of the total increase in built-up areas within the urban area over time. When applied to a small part of an urban area, such as the core city (or old part of the urban area), this indicator can be used to understand densification trends in urban areas.

Focus on a Pan-European perspective

Land is a finite resource and the way it is used is one of the principal drivers of environmental change, through which land use has a significant impact on the quality of life and ecosystems. In Europe, the proportion of total land use occupied by production (agriculture, forestry, etc.) is one of the highest on the planet and conflicting land-use demands require decisions that involve hard trade-offs. Land use in Europe is driven by a number of factors, such as the increasing demand for living space per person, the link between economic activity, increased mobility, and the growth of transport infrastructure, which usually result in urban uptake. Urbanisation rates vary substantially, with coastal and mountain areas among the most affected regions in Europe, as a result of the increasing demand for recreation and leisure.

[1] UN-Habitat Metadata on SDG Indicator11.3.1

[2] The United Nations Statistical Commission, in its 51st Session (March 2020) endorsed the Degree of Urbanisation (DEGURBA) as a workable method to delineate cities, urban and rural areas for international statistical comparisons.

In estimating the land consumption rate, 'consumption' of land needs to be carefully defined. Land consumption may be understood as (1) the expansion of built-up area which can be directly measured; (2) the absolute extent of land that is subject to exploitation by agriculture, forestry or other economic activities; and (3) the over-intensive exploitation of land that is used for agriculture and forestry (see EEA glossary). In the context of this indicator land consumption refers to the expansion of built-up area, i.e., the conversion of farmlands, forest, grasslands, or any other open space not under urban land use into residential, commercial, or other developed land uses.

Another important aspect of the definition of land consumption is the baseline that allows what is newly developed. In establishing the baseline, one needs to consider that in many areas of the world truly newly developed land is difficult to distinguish from redeveloped land. Therefore, and to establish a harmonized, transparent, and measurable indicator, it is suggested that land consumption is measured as the sealing of non-sealed areas with impermeable materials, such as concrete or asphalt.

In contrast, land take is defined as the change in the area of agricultural, forest and other semi-natural land taken for urban and other artificial land development (EEA, 2019). Land take includes areas sealed by construction and urban infrastructure, as well as urban green areas, and sport and leisure facilities.

The main drivers of land take are grouped as processes resulting in the extension of:

- housing, services, and recreation
- establishing sport facilities and public places
- industrial and commercial sites
- transport networks and infrastructures
- mines, quarries, and waste dumpsites
- construction sites

The spatial reference unit used for the computation is defined by the granularity of the input datasets. The granularity to be used is suggested to be the highest common spatial resolution or common minimum mapping unit of the two datasets. If aggregated values are reported, like for example administrative regions, the granularity of the spatial unit shall allow for meaningful aggregation.

2. METHODOLOGY

At the global level, the method to compute the ratio of land consumption rate to population requires[3]:

1) Delimitation of the urban area or city which will act as the geographical scope for the analysis
2) Spatial analysis and computation of the land consumption rate
3) Spatial analysis and computation of the population growth rate
4) Computation of the ratio of land consumption rate to population growth rate
5) Computation of recommended secondary indicators

The indicator relates the variation in land consumption with the variation in population in a reference period.

The computation of land consumption rate requires data on sealed land surface in a given reference spatial unit at observation time x1 contrasted to the same data at observation time x2, and computation of the population growth rate requires data on the number of inhabitants in the reference units at observation time x1 contrasted to the same data at observation time x2.

[3] A UN-Habitat training module on how to capture Land Use Efficiency is available.

The indicator addresses sustainable urbanization and integrated and sustainable human settlement planning and management. Therefore, one method for the computation of the indicator is using the Functional Urban Areas (FUAs) as reference unit where sustainable land consumption is measured. Other spatial units could be used alternatively, as it is the case of Local administrative units or cities.

A Functional Urban Area (FUA) consists of a 'City' and its 'Commuting zone', hence they consist of a densely inhabited city and a less densely populated commuting zone[4]. The boundary of a FUA may be subject to expansion as a city and its commuting zone spreads into the surrounding areas. The computation of land consumption rate to population rate needs to carefully address changing boundaries so that computed statistics are meaningful. There are three ways this can be done:

1) the indicator computation considers the changing boundaries and land consumption rate to population growth rate in year x1 and uses the FUA boundaries of year x1, whereas the computation in year x2 uses the new boundaries in year x2
2) for the computation of year x1 and for the computation of the indicator in all further years a fixed FUA boundary of year x1 is used
3) the FUA boundary is fixed to the FUA´s extent of the last observation year.

Figure 1 City boundaries from the Urban Atlas 2012 and 2018 dataset

Source: Urban Atlas.

In this context, it is suggested that a fixed FUA extent is used for the computation of the indicator, by fixing the FUAs extent to the extent of the first observation year (x1).

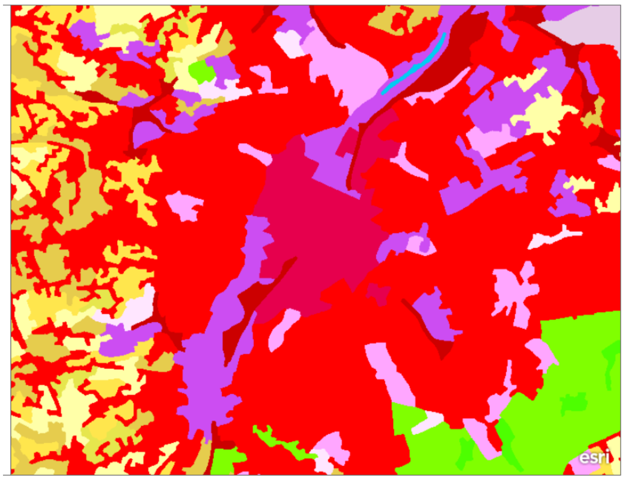
[4] The global DEGURBA definition 'Cities' (urban centres) consists of settlements with at least 50,000 inhabitants in contiguous dense grid cells (>1,500 inhabitants per km^2) and a Functional Urban Area is composed of a city plus its surrounding, less densely populated spatial units that make up the city's labour market, its commuting zone. The TERCET regulation defines Cities a local administrative unit (LAU) where the majority of the population lives in an urban centre of at least 50 000 inhabitants and the Functional Urban Area consists of a city and its commuting zone.

The indicator may also be derived for the entire landscape instead of addressing the FUAs only. Urban sprawl happens in scattered spatial pattern, typically with single or few houses spreading into the landscape occupying non-urban and non-sealed land. To correctly capture this large-scale process and thus in order not to underestimate the rate of sealing, the use of a high-resolution dataset is indispensable. For comparability reasons, the dataset should also compare all European countries, because with such large-scale land use processes, if different datasets are used, small differences in spatial resolution between countries may cause large differences and under- or overestimation of sealing.

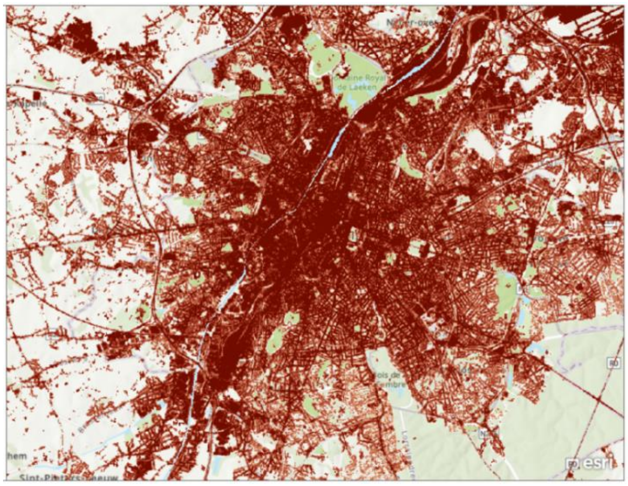
The Copernicus Land Monitoring Service delivers freely available land cover classifications from which the sealed surface can be derived for the entire landscape, in form of the Imperviousness dataset as well as the Corine Land Cover Dataset. The Minimum Mapping Unit (MMU) of the Corine Land Cover dataset is 25ha, which is rasterized at a 100m spatial resolution. This spatial detail does not allow capturing large-scale urban sprawl and resulting land sealing (Figure 2). The Imperviousness 2018 product is mapped at a 10m spatial resolution which allows capturing many more small landscape elements on large spatial scale. This is also true for the Urban Atlas dataset, which is produced on 0.5 ha MMU and rasterized at a 10m spatial resolution. However, to calculate land consumption for the entire landscape it is suggested to use the Imperviousness dataset.

Figure 2 Spatial detail of EO derived raster products with differing spatial resolution for the city of Brussels, Belgium

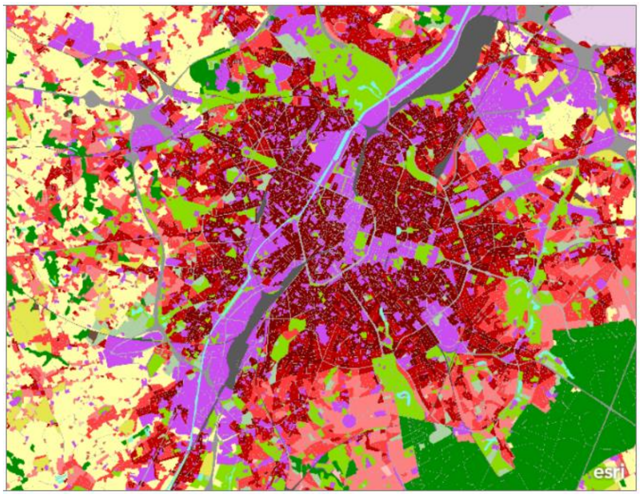
Corine Land Cover 2018



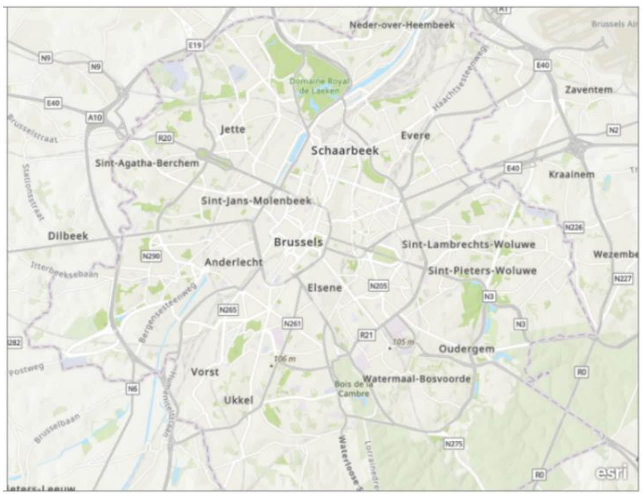
Imperviousness 2018



Urban Atlas 2018



Topographic background map



Source: Corine Land Cover; Imperviousness HRL; Urban Atlas.

3. DATA SOURCES

Geospatial data sources are available at the global level to calculate both components on the indicator. The global metadata mentions that the Global Human Settlement Layer (GHSL), the World Settlement Footprint (WSF), the Gridded Population of the World (GPW), WorldPop dataset, the High-Resolution Settlement Layer (HRSL), among others, can be used to attain global estimates for the indicator.

Using the Global Human Settlement Layer, the Joint Research Centre (JRC) has developed a tool, which can be adapted to other input data, to calculate the indicator 11.3.1 based on a proxy of Land Use Efficiency (LUE). JRC tool proposes to adapt the formulation of the Land Use Efficiency indicator to measure the change rate of the built-up area per capita. A script that can be installed in the toolbox of Quantum GIS (QGIS) has also been made available.

The World Settlement Footprint 2019 (WSF 2019) provides information on global human settlements with high level of detail (10m), featuring data from the Copernicus Sentinel-1 and Sentinel-2 missions. The World Settlement Footprint Evolution (WSF Evolution) has been generated by processing seven million images from the US Landsat satellite collected between 1985 and 2015 and illustrates the worldwide growth of human settlements on a year-by-year basis.

Table 1 Geospatial global data sources

Name	Source	Periods of reference available	Frequency	Spatial Resolution	MMU	INSPIRE Data Theme	Core data theme
GHSL BUILT	European Commission - JRC	1975, 1990, 2000 and 2014	Irregular	1 km, 250 m, 30 m	-	Land cover	Land cover
GHSL POP	European Commission - JRC	1975, 1990, 2000 and 2015	Irregular	1km, 250m, 9 arcsec, 30 arcsec	-	Population distribution	-
Gridded Population of the World (GPW)	CEDAC-NASA	2000, 2005, 2010, 2015, and 2020	5-years	1km (30 arcsec)		Population distribution	
WSF, human settlements	European Space Agency	2019	Irregular	10m	-	Land use	-
WAF, evolution	European Space Agency	1985-2015	Irregular	30m	-	Land use	
WSF, population	European Space Agency	2019	Irregular	10m	-	Population distribution	-

For the pan-European extent, two geospatial data sources are suggested to be used, both from the Copernicus Land Monitoring Service: the Imperviousness 2018 product and the Urban Atlas.

The Imperviousness 2018 High Resolution Layer (HRL)

The Imperviousness product captures the percentage of soil sealing for each 10m x 10m pixel. The Imperviousness HRL captures the spatial distribution of artificially sealed areas, including the level of sealing of the soil per area unit. The level of sealed soil (imperviousness degree 1-100%) is produced using a semi-automated classification, based on the calibrated NDVI (Normalized Difference Vegetation Index) derived from Sentinel 2 images. The Imperviousness datasets are available for the reference years 2006, 2009, 2012, 2015, and 2018. However, while the spatial resolution of the 2006-2015 layers is 20m x 20m, only the 2018 layer was produced on 10m spatial resolution. The two-fold increase of spatial resolution implies that Imperviousness values before the year 2018 cannot be compared with the dataset from the year 2018. As the next update will be done for the year 2021, update of imperviousness values can be expected in the year 2023.

The imperviousness portfolio contains two types of status layers:

1. Imperviousness Density (IMD)

The IMD product for 2018 indicates the percentage of sealed area within each 10m spatial resolution grid cells, which is also aggregated to a 100m product. The production is based on a supervised classification of sealed/non-sealed areas with subsequent visual improvement of classification results and derivation of degree of imperviousness based on median composites of the reference year for all Sentinel-2 spectral bands, the 90th percentile of the NDVI as well as the median of the Sentinel-1 VV and VH polarization backscatter. The SAR input did not always improve the result, but on the contrary, in some cases, had a negative effect on the result in some areas depending mainly on the relief and predominant land cover. For this reason, SAR data were not used for all EEA-39 tiles.

The previous 20m resolution (and aggregated 100m resolution) products were harmonized for the 2006-2015 period in a way that imperviousness status and change layers build a consistent time series, where imperviousness density changes are equal to the difference of subsequent imperviousness status layers. The great advantage of the increased resolution (10m) from 2018 onwards is that has led to the capturing of more details and hence more precise estimates of land uptake per capita. On the flipside, this also resulted in the new 10m resolution imperviousness product and its data model inconsistent with the previous time series especially in a statistical sense. Therefore, any assessment and product that is dependent on the time series must be broken into two parts, one before 2018 and one starting with 2018.

2. Impervious Built-up (IBU)

This product shows built-up areas, the part of the sealed surfaces where buildings can be found. Built-up areas are a sub-group of the sealed areas. It refers to areas where above-ground building constructions can be found. In contrast to the Imperviousness characterized by a continuous range of imperviousness measurements, built-up in the HRL 2018 is a binary product, expressed as built-up or non-built-up areas. This product is also available on a 10 meters resolution, as well as a 100 meters aggregated version called Share of Built-up (SBU)

While the information of what sealed area is in fact a building as opposed to e.g., a square in a city, for the SDG indicator on land consumption per capita the suggestion is to use the Imperviousness Density dataset. The reason for this is the loss of ecosystem services, such as e.g., cooling, carbon sequestration or flood protection in case the soil is sealed, which is independent from the sealing being a building or an open urban space.

The Urban Atlas dataset

The Urban Atlas provides pan-European comparable land cover and land use data for Functional Urban Areas (FUAs). The full dataset covers 788 FUAs covering EU27 + EFTA countries + West Balkans + Turkey + UK. Data production is based on visual image interpretation of very high-resolution Earth Observation datasets (Pléiades, KOMPSAT, Planet, SPOT6, SuperView, etc., with a spatial resolution of 2 x 2 or 4 x 4 meters).

The nomenclature of the Land Cover/Land Use product is the same as for the 2012 and 2018 versions. It includes 17 urban classes with MMU 0.25 ha and 10 Rural Classes with MMU 1ha. While the 2012 and 2018 Urban Atlas datasets cover 788 FUAs, the 2006 dataset was only produced for 319 FUAs and therefore is not suggested to be used for pan-European change detection.

The following classes are suggested to be accounted for land consumption when sealing is calculated from the Urban Atlas dataset:

Code	Label
1111	High density urban fabric
1121	Medium density urban fabric
1122	Low density urban fabric
1123	Isolated or very low-density urban fabric
1210	Industrial or commercial units
1221	Road and rail networks and associated land
1222	Major stations
1230	Port areas
1241	Airport areas
1242	Airport terminals
1330	Construction sites
1422	Sport and leisure built-up

Table 2 Geospatial Pan-European data sources

Name	Source	Periods of reference available	Frequency	Spatial Resolution	MMU	INSPIRE Data Theme	Core data theme
Imperviousness	Copernicus land monitoring service	2018	3yrs	10m grid	NaN	Land cover Land use	Land cover
Urban Atlas	Copernicus Land Monitoring Service	2012 2018	6yrs (3 years from 2021 on)	10m grid	Classes with a code 1: 0,25ha; other classes 1 ha	Land cover Land use	Land cover
GEOSTAT 1km^2 population grid	European Commission	2006, 2011, 2018	Irregular	-	NUTS3	Population distribution	

At the EU level, the EU SDG indicator set defined by Eurostat provides a similar indicator to the global referring to the [Settlement area per capita] which captures the amount of settlement area due to land-take, such as for buildings, industrial and commercial areas, infrastructure and sports grounds, and includes both sealed and non-sealed surfaces. The indicator is based on the [LUCAS survey], which corresponds to a harmonised *in situ* land cover and land use data collection over EU's territory, based on a standardised methodology in terms of sampling plan, classifications, data collection and statistical estimators. Data is disseminated at NUTS 2 level, every three years.

Table 3 Statistical Pan-European data sources

Name	Source	Periods of reference available	Frequency	Max territorial granularity	Other relevant disaggregation	ESS regulation reference
Land Use /Cover Area frame Survey	ESTAT-LUCAS	2012, 2015 and 2018 (EU 27 MS)	3-years	NUTS 2	-	Part of the Community Statistical Programme

At the national level, national land use and land cover maps can also be used to capture land consumption and provide detailed territorial results. In case of Portugal, the Land Use and Land Cover Map (COS) can also be used to compute this indicator with a greater territorial disaggregation. COS corresponds to a national product under the responsibility of the Directorate-General for Territory (Portuguese NMCA). Data series are available for Mainland Portugal and correspond to polygonal maps that represent homogenous land use/cover units. COS is based on a vector data model with a MMU of 1 ha. The nomenclature of COS 2018 consists of four levels of detail that can be grouped into 9 classes of first level of detail (1 - Artificial land; 2 - Cropland area; 3 - Grassland area; 4 – Agroforestry areas; 5 - Forest area; 6 - Shrubland area; 7 - Open spaces or sparce vegetated areas; 8 - Wetlands; 9 - Surface water bodies) and there is a common and comparable subset of 83 LCLU classes.

Table 4 Geospatial National Data Sources

Name	Source	Periods of reference available	Frequency	Spatial Resolution	MMU	INSPIRE Data Theme	Core Data Theme
PT- Land Use/Cover Map (COS)	Directorate-General for Territory	1995, 2007, 2010, 2015 and 2018	Irregular, expected to be every 3 years	20 m	1 ha	Land Cover Land Use	Land Cover

4. COMPUTATION

In detail, the indicator is defined as the ratio of land consumption rate (LCR) to population growth rate (PGR):

$$LCR/PGR = [((At{+}n - At)/At)/T] \,/\, [ln(Popt{+}n/Popt)/y],$$

where:

LCR = land consumption rate
PGR = population growth rate
At = Total areal extent of the consumed land for the first year
At+n= Total areal extent of the consumed land for the last year
T *= Number of years between= At+n and At*
$Popt$ *= Total population in the first year*
$Popt{+}n$ *= Total population in the last year*
y *= Number of years between the two measurement periods*

The rate of change in land consumption and population can assume positive values if both the nominator and denominator increase in the given period (At < At+n, Popt < Popt+n). In case both land consumption and population change are negative (in case of e.g., more land recultivation than land take together with decreasing population), the rate of the change will be negative.

Increasing land consumption

Considering recent land take trends, it is not likely that land consumption becomes negative. Following the assumption of increasing land consumption (LCR ≥0), the sign of the LCR/PGR ratio mostly follows population variation, i.e., the denominator of the ratio, as below:

1) LCR/PGR = 0: Land consumption did not vary in the period considered.

2) LCR/PGR > 0

- 0 < LCR/PGR < 1: Both land consumption and population change are positive, but the population increases more than land consumption.

- LCR/PGR > 1: Both land consumption and population change are positive, but land consumption increases more than the population.

3) LCR/PGR < 0

- -1 < LCR/PGR < 0: Population change is negative and, in absolute value, greater than land consumption increase.
- LCR/PGR < -1: Population change is negative and, in absolute value, the decrease in population is less than the increase in land consumption.

Decreasing land consumption

Negative land consumption rates (LCR < 0) may, however, still occur, for example, due to recultivation or land recycling, in which case the indicator may take the following values:

1) LCR/PGR > 0

- 0 < LCR/PGR < 1: Both land consumption and population change are negative, but the population decreases more than land consumption.
- LCR/PGR > 1: Both land consumption and population change are negative, but land consumption decreases more than the population.

2) LCR/PGR < 0

- 0 > LCR/PGR > -1: Population is increasing, and it is greater than the absolute value of the of land consumption decrease.
- LCR/PGR < -1: Population is increasing, and it is less than the absolute value of land consumption.

The interpretation of the indicator may become quite cumbersome, because the understanding of the various change combinations is not straightforward as they can take a variety of positive and negative combinations.

Therefore, in addition to the above definition, the calculation of a second indicator is suggested, such as:

$$LCR/PGR = (At+n/Popt+n) - (At/Popt)$$

where:

LCR = land consumption rate
PGR = population growth rate
At = Total areal extent of the consumed land for the first year
At+n= Total areal extent of the consumed land for the last year
Popt = Total population in the first year
Popt+n = Total population in the last year

The JRC has also proposed the Land Use Efficiency (LUE) formulation as a proxy to the global indicators, as a way to deal with the dynamics of cities with negative or zero population growth; or cities that due to disasters have lost part of their territories. JRC has also developed a tool to calculate LUE using the Global Human Settlement Layer, which can be adapted to other input data. The formula includes a normalization to express a variation of artificial land by inhabitant for a period of 10 years.

$$LUE = [((TA\_n/ Pop\_n) - (TA\_ n+x/ Pop\_ n+x) / (TA\_n / Pop\_n) \times 100)]x(10/N)$$

where:

TA_n = artificial land in moment (n)
Pop_n = resident population in artificial land in moment (n)
TA_n+x = artificial land in moment (n+x)
Pop_n+x = resident population in artificial land in moment (n+x)
N = years between observations

Additionally, the proposed recommended secondary indicators at the global level should also be used to complement the analysis of the phenomenon.

The 'built-up area per capita' is computed by dividing the total built-up area by the total urban population within the urban area/city at a given year, using the formula below:

Built-up area per capita (m2/inhab.) = UrBUt / Popt

where:

UrBUt = total built-up area/city in the urban area in time t (in square meters)

Popt = population in the urban area in time t

The 'total change in built-up area' is measured using the same inputs as the land consumption rate for the different analysis years, based on the below formula:

Total change in built-up area (%) = (UrBUT+n – UrBUt) / UrBUt

where:

UrBUt +n = total built-up area in the urban area/city in time the current/final year

UrBUt = total built-up area in the urban area/city in time the past/initial year

5. RESULTS

Results based on Pan-European data sources

To achieve the best possible spatial representation of real-world soil sealing the input dataset must have the highest possible spatial resolution and the computation must be performed on that same data source. Results are, however, presented on an aggregated level, for the countries or NUTS3 regions or alternatively, as in the present case for Functional Urban Areas (FUAs).

Using the Copernicus Urban Atlas dataset, the indicator can be calculated between 2012 and 2018. From 2021 on the indicator can be calculated every 3 years. The indicator is calculated for the EEA-39 regions (EEA-38 + UK), i.e., for 39 countries in Europe. The European Environment Agency provides a dashboard where the data can be explored in form of charts, tables and maps using interactive queries. Results of the queries can be downloaded in a tabular format, as well as images in case of maps or charts. The database can be accessed for all countries or for selected countries only, and the data can be extracted for each FUA as well as for the cities and the commuting zones within each FUA. The indicator land consumption per capita is derived from the Copernicus Urban Atlas dataset for 2012-2018 for 38 European countries (apart from Turkey, where population change dataset was not available).

There are differences in the 2012-2018 land uptake per capita patterns between core cities and commuting zones, both considering the EU coverage and the entire EEA38 + UK territory. The artificial area per capita of FUAs in the EEA38 + UK territory amounted to 451 m^2/capita in 2012 and decreased to 449m^2/capita in 2012, whereas in the EU27+UK region land consumption per capita declined from 423m^2 418m2 per capita.

Core cities. In core cities in the EU artificial area per capita in 2018 is almost 70% less compared to commuting areas with 224 m^2 per capita and shows a decreasing trend. The range of this indicator is considerable, the lowest values can be observed in Athens and Thessaloniki with only 50 m² per capita and the highest values with 950 m² per capita in Umeå and Kuopio in Sweden as well as Lorca in Spain.

Commuting Areas. In 2018, the amount of artificial area per capita amounted to 691 m² per capita and decreased by 16 m² since 2012. Lowest rates with less than 100 m² per capita can be observed in the South of Europe in particular Messina, Caserta, Acireale and Cádiz. At the other end of the scale very high values with more than 2 500 m² per capita can be observed in commuting areas scattered all the European Union but mainly part of small cities as is the case in Uppsala (SE), Umeå (SE), Dobrich (BG), Daugavpils (LV), Jyväskyla (FI), Lugo (ES), Kuopio (FI).

Country trends.

Looking at trends in the Member States it can be observed that the countries Malta, Greece, and Spain have the lowest rates or artificial area per capita, both in core cities and commuting areas (Figure 2 and 3).

Core cities. In core cities the amount of artificial area per capita is lowest in Greece, Spain, Romania, Malta, Austria, and France, where this indicator is below 200 m² per capita (see). Half of the Member States show a decreasing trend between 2012 and 2018. The highest values can be observed in Sweden and Finland with more than 400 m² per capita, but at the same time high decreases with on average 30 m² per capita were achieved in these countries.

Commuting areas. Regarding commuting areas (see) largest increases of the amount of artificial area per capita can be observed in the Baltic region with on average more than 50 m² per capita between 2012 and 2018. However, some positive trends are also visible in countries where the rate of artificial area per capita was very high in 2012, among these are Finland (minus 42 m² per capita), Sweden (minus 58 m² per capita) and Austria, Slovenia, and Ireland (on average minus 20m² per capita).

Figure 3 Built-up area per capita by Core Cities, 2012 and 2018

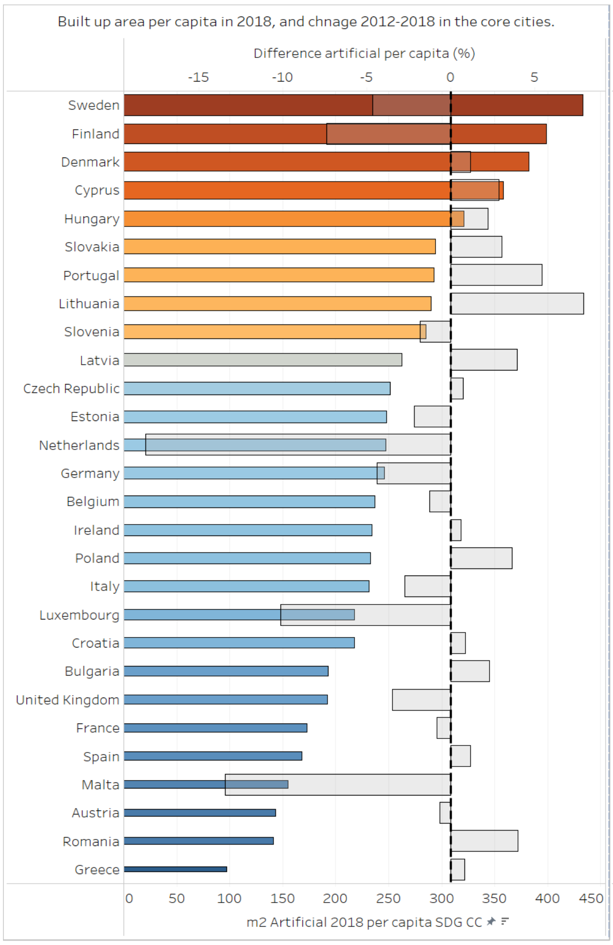
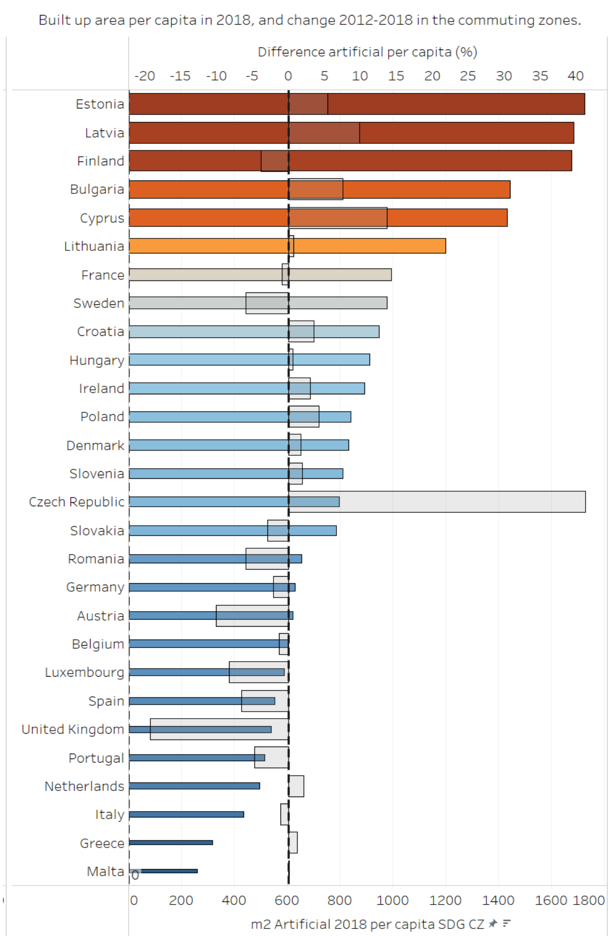


Figure 4 Built-up area per capita by Commuting Zones, 2012 and 2018

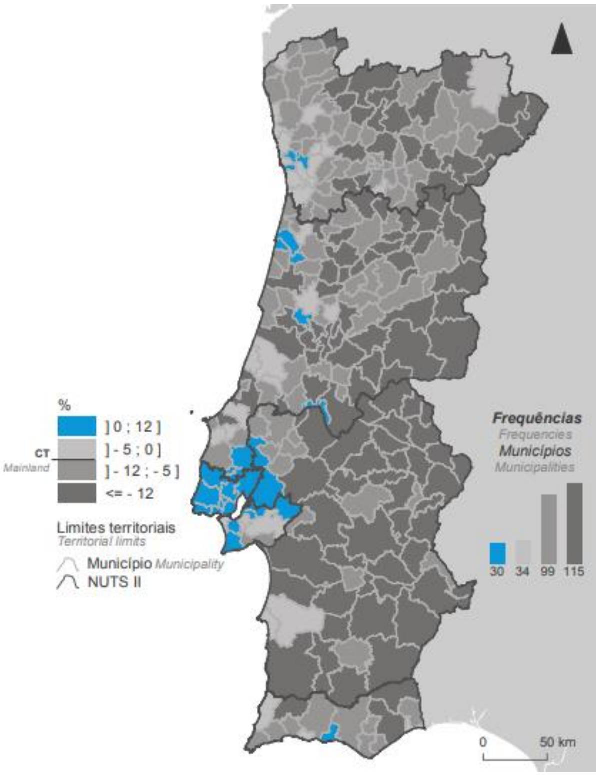


Source: EEA.

Results based on Geospatial National data sources

Portugal calculates the *proxy* indicator based on the LUE formula, which establishes an average variation for a 10-year period. This indicator, published under the Land Use Land Cover Statistics, is based on data from the national Land Use Land Cover Map (COS 2010, C0S 2015 and COS 2018), assuming the level 1 class "artificial territories" to which the "areas under construction" were excluded, and on data from the annual resident population estimates for the correspondent years.

Figure 5 Efficiency evolution of the artificial land by inhabitant and municipality, 2018



Source: Statistics Portugal, Land Use Land Cover Statistics.

In 2018, Mainland Portugal registered a -5.0% evolution of the efficiency of artificial territories land per inhabitant, corresponding to a normalized result for 10 years (in 2015, this value corresponded to -9.5%).

The territorial disaggregation of this indicator by municipality shows that, in 2018, only 30 municipalities registered a positive evolution regarding the efficiency of artificial territories per capita. These corresponded largely to municipalities located in the Área Metropolitana de Lisboa and to municipalities contiguous to this metropolitan territory. In addition, for a group of 33 municipalities located mainly in the coast of the Norte and Centro regions of Mainland Portugal, there was a decrease of the efficiency of the artificial territories per inhabitant that was less significant than the one recorded for the Portugal's mainland average (-5.0%).

B. NORMATIVE GUIDELINES

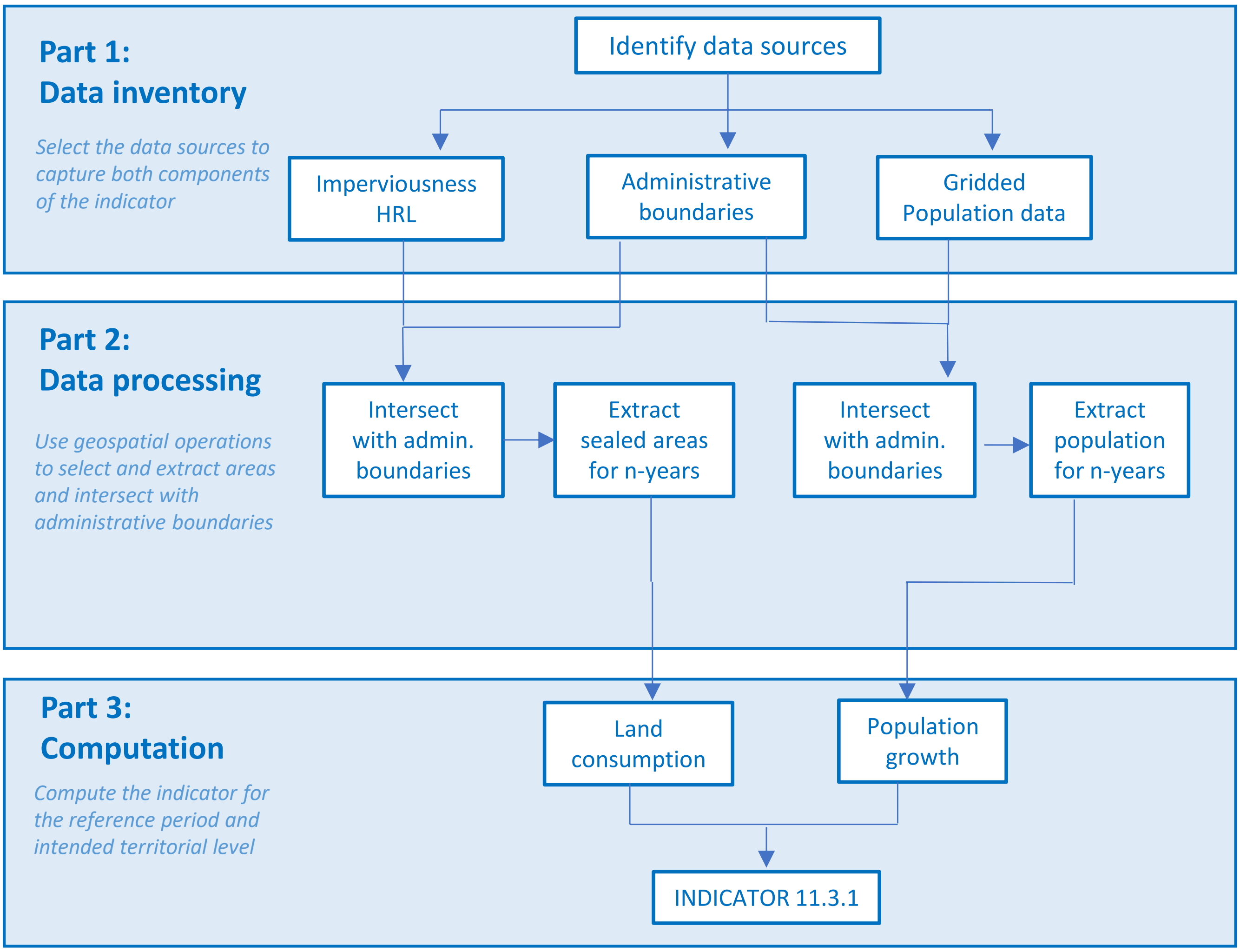
1. ALGORITHM WORKFLOW

The computation steps for the calculation of this indicator are relatively straightforward and the algorithm workflow can be divided into three main phases:

- Data inventory, which involves selecting the data source to capture both components of the indicator.
- Data processing, in which all data needed for indicator computation are processed to allow capturing both components of the indicator
- Computation, in which the final value of the indicator is computed by making use of the indicator's formula

The following diagram summarises processing steps divided into the three main phases for indicator calculation, having the proposed Pan-European data sources as a reference. The same workflow can be applied other geospatial data sources.

Figure 6 Chart summarising the steps for indicator computation



2. RECOMMENDATIONS

- Population and land consumption are dynamically changing variables. Therefore, monitoring should be performed at regular intervals and the intervals should not be longer than approximately 5 years. For the European countries the European Environment Agency supports monitoring with regular updates of every 3 years.

- Until the year 2023, when the CLMS 2021 imperviousness dataset will become available, the indicator land uptake per capita shall be derived from the Urban Atlas dataset covering 788 Functional Urban Areas. From 2023 on, the indicator can be calculated from the CLMS Imperviousness dataset with the advantage of covering the entire EEA-39 region and hence better indicating large scale scattered urban and industrial sprawl patterns.

- Changing boundaries of FUAs can complicate comparability of the various observation year and, therefore, it is recommended to fix the FUA boundary for the computation of the indicator, the boundary is fixed at the extent of the first observation year.

- To better understand change patterns, results should be disaggregated by location, e.g., in case of FUAs the disaggregation of cities and commuting zones should be used. Further disaggregation could be achieved by using income levels and urban typology.

- The understanding of the various change combinations is not straightforward in the computation of the indicator based on the proposed global formula. Therefore, it is recommended the computation and analysis of the secondary indicators, such as the built-up area per capita. The LUE formulation can also, alternatively, be used with the advantage of providing an average variation for a 10-year period

- Indicator metadata shall always indicate the time interval of each component´s measurement. Both components, i.e., land consumption and population growth, shall be measured in the same time interval.

- Land consumption, as in this indicator, shall be differentiated from land take in the global indicator metadata. Land take is the conversion of non-urban, semi-natural land to urban areas, irrespective of the land cover. This means that conversion into urban parks, football fields or golf courses as well as into construction sites, parking plots etc. are equally considered land take. Land consumption on the other hand is defined as the sealing of semi-natural lands and hence the conversion into green urban areas shall not be incorporated in the indicator.