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MODULE 3

LAND CONSUMPTION

UN-HABITAT
FOR A BETTER URBAN FUTURE

LAND CONSUMPTION

TARGET 11.3: *By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries.*

Indicator 11.3.1: *Ratio of land consumption rate to population growth rate*

1. INTRODUCTION

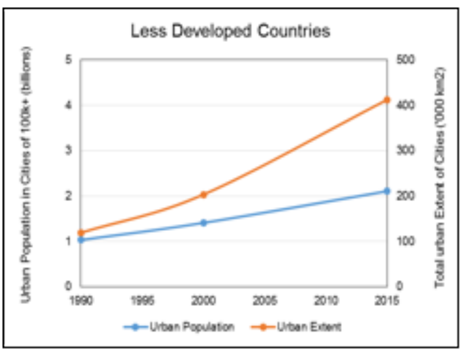
1.1 Background

Land cover is altered principally by direct human use: through agriculture and livestock raising, forest harvesting and management and urban and suburban construction and development. A defining feature of many of the world's cities is an outward expansion far beyond formal administrative boundaries, largely propelled by the use of the automobile, poor urban and regional planning and land speculation. A large proportion of cities both from developed and developing countries have high consuming suburban expansion patterns, characterized by city boundaries often extending to further peripheries.

Cities require an orderly urban expansion that makes the land use more efficient. As they expand, cities need to plan for future internal population growth and city growth resulting from migrations as well as to accommodate new and thriving urban functions such as transportations routes. In order to effectively monitor land consumption growth, it is vital not only to have information on existing land use cover but also on the capability to monitor the dynamics of land use resulting from both changing demands of increasing population and forces of nature acing to shape the landscape.

This indicator is connected to many other SDG indicators: 11.7.1 (Public space), 11.a.1 (Regional Development Plans); 15.1.2 (Forest area), 8.1.1 (City Product per Capita); 8.2.1 (Growth rate per employment); 8.5.2 (Unemployment Rate); 11.6.1 (Solid Waste Collection).

It ensures that the SDGs integrate the wider dimensions of space, population and land adequately, providing the framework for the implementation of other goals such as poverty, health, education, energy, inequalities and climate change. The indicator has a multipurpose measurement, as it is not only related to the type/form of the urbanization pattern but also, it captures the various dimensions of land use efficiency: economic (proximity of factors of production); environmental (lower per capita rates of resource use and GHG emissions), social (reduced travel distance and cost expended).



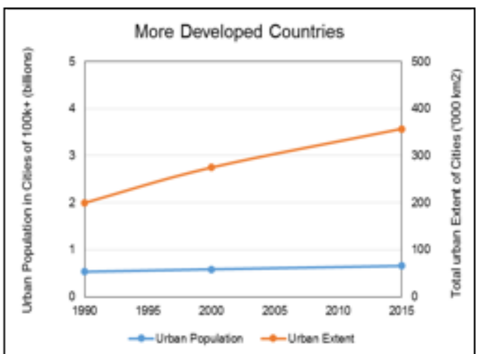


Figure 1: Global results of urban extent densities @ Atlas of Urban Expansion -NYU

Global Results: Urban extent densities in Less Developed Countries – 3.3 times higher than densities in More Developed Countries in 1990 – declined at an average annual rate of 2.1% between 1990 and 2015 (left). In More Developed Countries densities declined at 1.5% during this period (right). Urban land consumption per capita in these regions increased at similar rates.

1.2 Rationale for Monitoring

In many cities, land consumption is increasing much more rapidly than population growth. The built-up environment configuration influences the management processes for development and other municipality actions. Population growth on the other hand affects the availability of land for different purposes in its spatial distribution. While determining future growing-areas, monitoring city growth has an important role in urban development.

To achieve inclusive and sustainable urbanization, urbanization process needs to utilize resources in a manner that can accommodate population growth from migration and natural increase while preserving environmentally sensitive areas from development and limiting drawdowns of non-fungible hinterland resources such as water and waste disposal space.

The purpose of monitoring progress against the SDG indicator 11.3.1 is therefore to provide the necessary and timely information to decision makers and stakeholders in order to accelerate progress against the target and goal.

This indicator on land use efficiency seeks to measure, benchmark and monitor the relationship between land consumption and population growth to enable decision-makers to track and mange urban growth at multiple scales to promote orderly urban expansion. To prevent unsustainable increases on land consumption, beyond those driven by the population growth rate, policies should take into consideration the different aspects of density as well as interaction with other indicators.

Meeting Target 11.3 by 2030 requires, at the minimum, slowing down the decline in compactness and, if possible, ensuring that the compactness of cities is maintained or increased over time.

a) Monitoring and reporting process

National and city governments have the primary role in controlling land use for sustainable urbanization thus to be effective, the monitoring framework will require their full support and ownership.

DATA COLLECTION

National Statistical Agencies are responsible for data collection. However, for this particular indicator, population data is available for all cities and countries (UN-DESA population data) and satellite data from open sources.

CAPACITY DEVELOPMENT

UN-Habitat and other partner institutions such as New York University, the Global Human Settlement Layers (GHSL) team and ESRI will support various components for reporting on this indicator. UN-Habitat will lead global responsibility of capacity building of national statistical agencies.

DATA RELEASE

Monitoring of the indicator will be repeated at regular intervals of 5 years, allowing for three reporting points until 2030.

Data at the regional levels will be estimated from national figures derived from national sample of cities. Regional estimates will incorporate national representations using a weighting by population sizes.

Global monitoring will be led by UN-Habitat with the support of other partners and regional commissions.

1.3 Concepts and Definitions

POPULATION GROWTH

The rate at which population size changes in a country during a period, usually one year, expressed as a percentage of the population at the start of that period.

LAND CONSUMPTION

This refers to the uptake of land by urban developments.

URBAN EXTENT

Defined as the proposed area of study that comprises of the contiguous built-up area and urbanized open space of the city, along with areas added by proximity analysis.

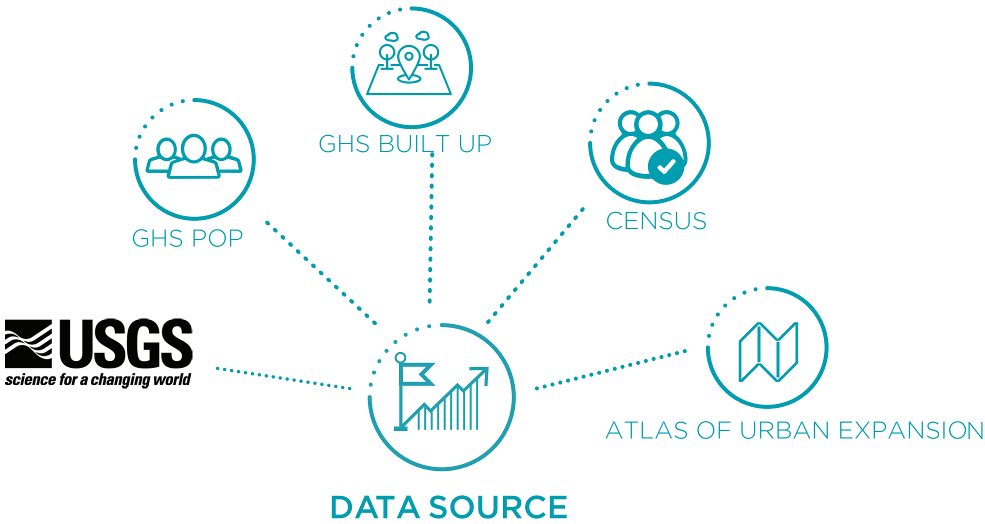
URBAN EXTENT DENSITY

Defined as the ratio of the total population of the city and its urban extent, measured in persons per hectare. It measures the intensity of use of the urban extent of a city by its population.

2. HOW DO WE MEASURE LAND CONSUMPTION TO POPULATION GROWTH RATE?

Monitoring the ratio of urban expansion to population growth rate requires a model composed of three layers on information, and three methodological steps

Data is available from the following sources:



OTHER SOURCES

1. Free satellite Imagery at a spatial resolution of 15-30m
2. Built-up maps, population density maps and settlement maps.
3. Population data
4. Urban extents/density,

ADDITIONAL DATA REQUIREMENTS

To calculate the indicator, the time interval for both population and satellite imagery is required. The time interval is dependent on the census year that varies from country to country.

The criterion to choose the images is:

- Availability
- Cloud coverage, fewer than 5% for the study area
- Same month to minimize the changes generated by rainy or drought seasons, phases of crops and others.
- Full coverage of the city to avoid image mosaics
- Similar spectral bands

SOFTWARE

Desktop GIS (commercial or open source)

The computation of this indicator is based on three methodological steps:

1. Measuring the urban extent
2. Assigning population to the urban extent
3. Calculating the indicator

Unit 1: Measuring the urban extent

The urban extent is the proposed area of study that comprises of the built-up area and urbanized open space of the city, along with areas added by proximity analysis. The measurement (calculation of size) of urban extent follows classification of satellite imagery (30 m by 30 m spatial resolution or higher). The following procedure is used to determine the urban extent:

Step 1: The satellite imagery is classified into any of the 3 classes: Built-up, Open space (mainly refers to unbuilt areas including open countryside, forests, crop fields, parks, unbuilt urban areas, cleared land) and Water.

Following the 3-way classification, a consistent and reliable methodology is then employed for defining the spatial extent of the city as a unit of analysis:

Step 2: Sub-classify the built-up area pixels into three types i.e. urban, suburban and rural depending on the share of built-up density (urbanness) in a 1km^2 circle around each pixel.

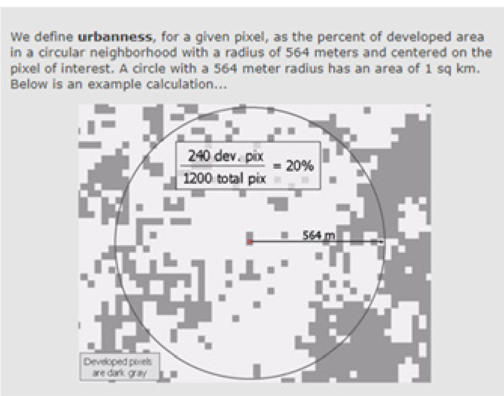


Figure 11: 1km2 circle to calculate share of urbanness

The ranges to obtain this sub classification

For cities with populations greater than 50,000, the range is:

↑ 50% **built-up**

↑ 25% - 50% **built-up**

↓ 25% **built-up**

For cities with populations of less than 50,000, the suburban category is eliminated and the new range is:

↑ 25% **built-up**

↓ 25% **built-up**

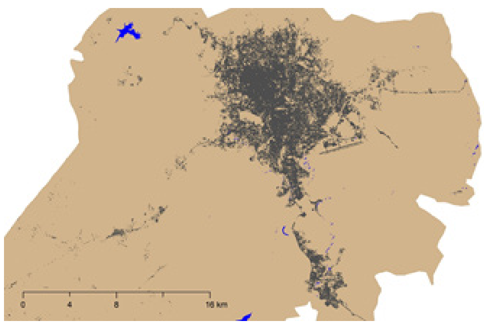


Figure 3: Built-up pixels for Addis Ababa, Ethiopia© Atlas of Urban Expansion, New York University

STEP TWO (a):
The first sub-classification is urban pixels (brown), or those built up pixels that have the densest (More than 50%) share of built up area in their 1 km^2 circles.

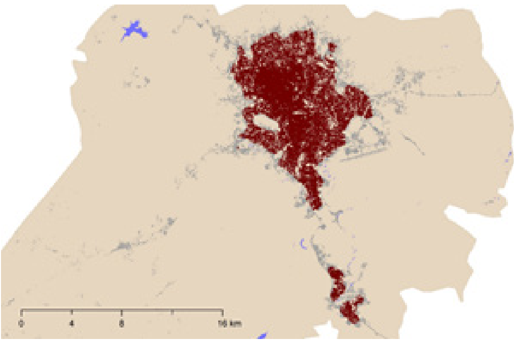


Figure4: Built-up Area sub-classified into urban pixels© Atlas of Urban Expansion, New York University

STEP TWO (b):
Next, the built-up area (Figure 5) is classified into suburban pixels (red).

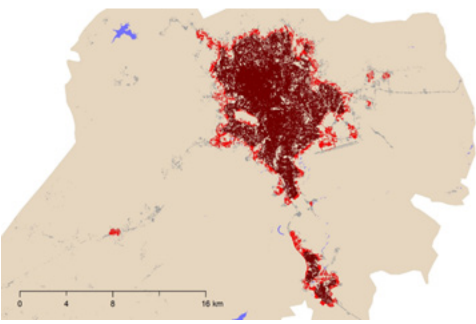


Figure 5: The Built-up Area sub-classified into Suburban© Atlas of Urban Expansion, New York University

STEP TWO (c):
Next, sub-classify the built-up pixels into rural pixels (orange).

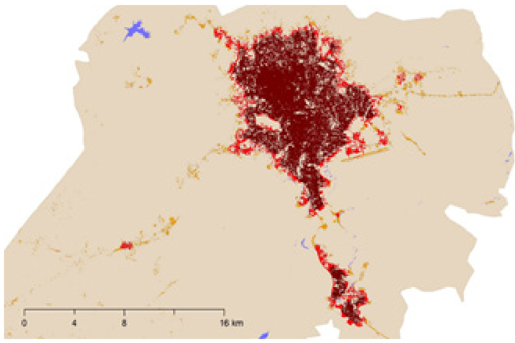


Figure 6: The Built-up Area sub-classified into rural pixels© Atlas of Urban Expansion, New York University

All the built-up pixels have been now classified into one of the three categories as illustrated:

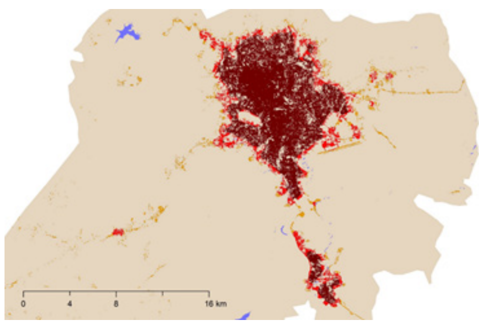


Figure7: The Built-up Area is sub-classified into three types: Urban + Suburban + Rural pixels© Atlas of Urban Expansion, New York University

STEP THREE:

The next process involves sub-classifying the open space pixels into three types i.e. fringe open spaces, captured open space and rural open spaces.

Fringe open space refers to open spaces areas within 100 meters of urban and suburban areas.

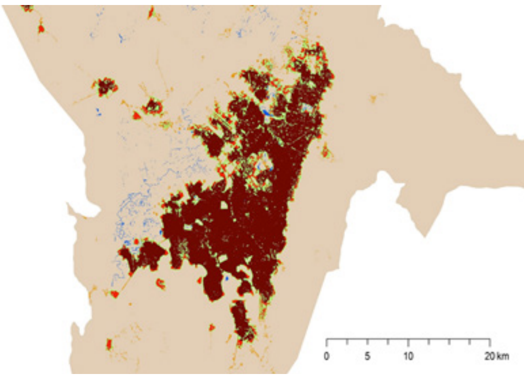


Figure8: Fringe Open Space Pixels© Atlas of Urban Expansion, New York University

Fringe Open space represent the edge-disturbance zone between relatively dense built-up areas and the surrounding countryside.

Captured open space refers to all open space clusters that are fully surrounded by fringe open space and has an area of less than 200 hectares

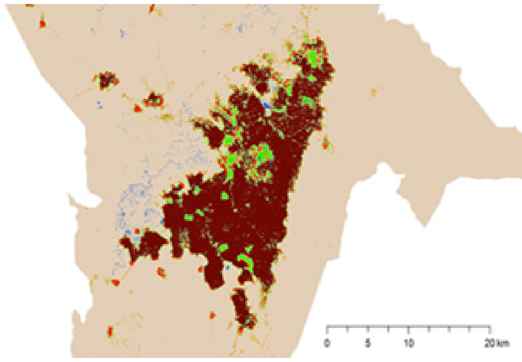


Figure 9: Captured Open Space Pixels© Atlas of Urban Expansion, New York University

Rural open space refers to open space that is neither fringe nor captured open space.

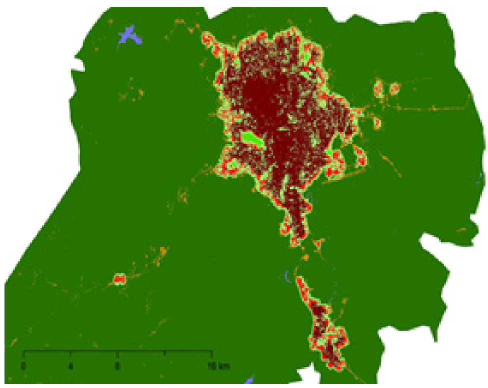


Figure 10: Open Space sub-classified into three types: Fringe Open Space + Captured Open Space + Rural Open Space© Atlas of Urban Expansion, New York University

STEP FOUR :

The sub-classification of built-up area and open space is the input into a clustering analysis that groups built up areas and open spaces into a unified urban extent (gray).

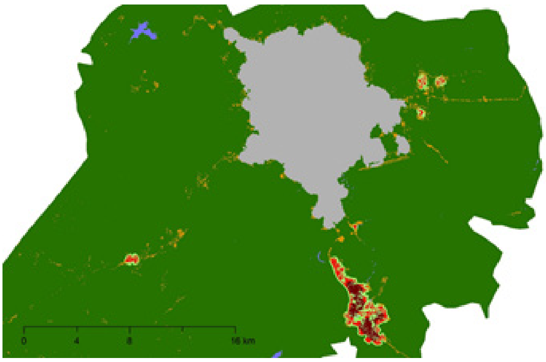


Figure 11: A unified Urban Extent© Atlas of Urban Expansion, New York University

For a given city, the process described above is repeated over time (base year and current year) - collecting Landsat imagery, classifying pixels, determining urban extent to study change in built-up area associated with the city.

Note:

The urban extent includes:

All the buildings (all the isolated buildings that are more than 100 meters from an urban or suburban area, as those typical of rural are not included in the urban extent).

The small open space areas (<200ha) that are totally surrounded by buildings

The open space fringe that is within 100 meters of urban and suburban areas.

The urban extent excludes:

The exterior open countryside

Big open space areas (>200 ha) that are surrounded by buildings.

Some exceptions include:

Rivers: urban and suburban areas separated from the main urban area by a river must be included within the continuous footprint.

Unit 2: Population Assignment

It is important to determine the exact population within the urban extent as defined in Unit 1: This is vital for monitoring of SDG 11. The objective of harmonizing the population is to allow for comparisons within and between countries. The strategy involves disaggregating population data to the built-up pixel level creating a population grid.

The following procedure is used for population assignment:

Step 1: Gather data for all administrative areas intersecting the urban extent, including population data (geo-coded)
Step 2: Interpolate population data to match satellite imagery data.
Step 3: Evenly divide population of each administrative area between every built-up pixel.
Step 4: Sum the population of the built-up pixels falling within the urban extent.

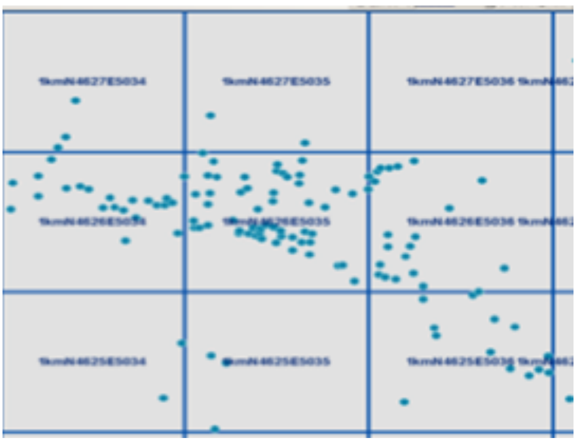


Figure 12: Point data overlaid on a statistical grid net @Eurostat

Figure 13: Grid cells with aggregated point information @ Eurostat

IN EACH PERIOD,

1. Calculate population growth rate based on population within the urban extent between periods.

To estimate the population growth rate:

$$PGR = \frac{(LN(Pop_{(t+n)}/Pop_t)}{(y)}$$

Where

Pop_t Total population within the urban extent in the past/initial year
Pop_{t+n} Total population within the urban extent in the current/final year
y The number of years between the two measurements periods

2. Calculate rate of change between periods (land consumption rate)

The rate of land consumption is calculated from the resulting coverage maps according to the following formula:

$$LCR = \frac{(LN(Urb_{(t+n)}/Urb_t)}{(y)}$$

Where

Urb_t The Urban extent in km^2 for past/initial year
Urb_{t+n} The Urban extent in km^2 for current year
y The number of years between the two measurement periods

Interpretation of results

Ideally, an accepted ratio of land consumption to population growth rate should equal one. In cities where this ratio is higher, progress on this indicator should be measured by reduction of the baselines moving towards one. In the cities where this ratio is higher, progress on this indicator should be measured by reduction of the baselines moving towards one. However, numerous exceptions can be identified in the measurement of this indicator (i.e. overcrowding/saturation/ high-plot coverage or on the contrary low growth rates and densities/large urban areas). The indicator is supposed to be interpreted as follows:

The indicator is supposed to be interpreted as follows:

City Urban extent density	Indicator Value	
10-150 persons/hectare	Below 1: Efficient land use	Above 1: Inefficient land use
151 -250 persons/hectare	Below 1: Moving toward efficiency	Above 1: Moving away from efficiency
Greater than 250 persons/ hectare	Below 1: Insufficient land per person	Above 1: Moving toward sufficient land per person
If the indicator is *positive*, it means the city is converging on the norm while if it is *negative,* it means the city is moving away from the norm by those percentage points.		

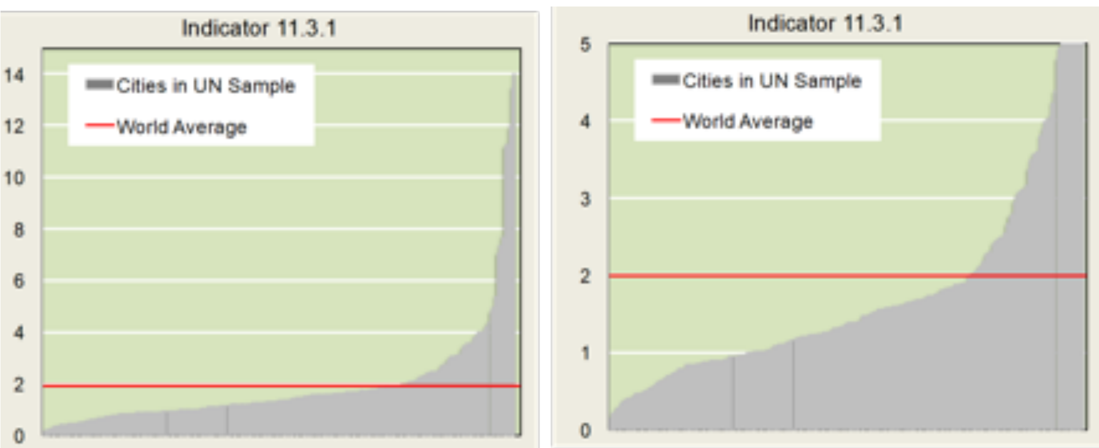


Figure 1: Indicator 11.3.1 results from 200 City UN Sample © Atlas of Urban expansion-NYU

Value of >1 indicates that city is moving in the direction of using less land per person. (Right)

Value of <1 indicates that city is moving in the direction of using more land per person (left)

Examples

Data acquired from the Atlas of Urban Expansion project

Example 1: Accra, Ghana in 2000 and 2014.

Year	2000	2014
Population	2,513,025	4,429,649
Urban Extent (in hectares)	41,241	87,272
Population density (persons per hectare)	61	51

Part 1: Estimating the population growth rate

$$PGR = \frac{(LN(Pop_{(t+n)}/Pop_t\ )}{(y)}$$

$$PGR = \frac{(LN(4{,}429{,}649/2{,}513{,}025)}{(14)}$$

PGR= 0.040

Part 2: Estimating the land use consumption rate

$$LCR = \frac{(LN(Urb_{(t+n)}/Urb_t\ )}{(y)}$$

$$LCR = \frac{(LN(87{,}212/41{,}241)}{(14)}$$

LCR= 0.053

The formula to estimate the ratio of land consumption rate to population growth rate (LCRPGR) is provided as follows:

$$LCRPGR = \frac{(\text{Annual Land Consumption rate})}{(\text{Annual Population growth rate})}$$

$$LCRPGR = \frac{0.053}{0.040}$$

LCRPGR =1.325

In this example for Accra, a city with an urban extent density of 51 with LCRPG that is greater than 1 is using land inefficiently. However, the urban extent population density is still below a sustainable range. This means that densities are still sufficient to sustain public transportation. However, it may be necessary for the city government to consider changing laws that prevent higher densities in new developments - such as plot coverage laws or building height restrictions or minimum floor space standards.

Example 2: Anqing, China in 1990 and 2000.

Year	1990	2000
Population	406,456	353,996
Urban Extent (in hectares)	3,436	4,739
Population density (persons per hectare)	118	75

Part 1: Estimating the population growth rate

$$PGR = \frac{(LN(Pop_{(t+n)}/Pop_t\ )}{(y)}$$

PGR=(LN (353,996 / 406,456))/10

PGR = 0.006

Part 2: Estimating the land use consumption rate

$$LCR = \frac{(LN(Urb_{(t+n)}/Urb_t\ )}{(y)}$$

LCR=(LN(4,739/3,436))/10

LCR=0.013

The formula to estimate the ratio of land consumption rate to population growth rate (LCRPGR) is provided as follows:

$$LCRPGR = \frac{(\text{Annual Land Consumption rate})}{(\text{Annual Population growth rate})}$$

LCRPGR= (0.013)/(-0.006)

LCRPGR = -2.16

In this example for Anging, a city with an urban extent density of 75 with LCRPG that is less than 1 (-2.16) is using land inefficiently since it already has low density and the density is falling.

3. GENERAL LIMITATIONS

Data Limitations	Possible Solutions
Measurement of urban expansion by conurbations of two or more urban areas that are in close proximity is a challenge, especially the attributions to urban growth. Lack of coinciding to administrative levels, boundaries and built-up areas	Efforts to use area of reference at the level of the built-up area of the urban agglomeration should be taken into consideration
Conflicting definitions of the city	Requires proper definition of the city boundaries
Experience difficulties in capturing cities with negative or zero population growth	Baseline/benchmark of population density and its changes over time must be taken into consideration
In the absence of GIS layers, this indicator may not be computed as defined.	Alternative measures of acquiring land that is developed /consumed per year Monitor the efficient use of urban land by measuring the densities in residential zones that any city plans or international guidance
Planned densities vary greatly from country to country, and at times city to city	At sub-regional or city levels, it is more appropriate to compare average densities achieved currently to those achieved in the recent past
Data interpretation could present challenges especially when aggregating the measure for more than one city.	To consider the possibility of using high and low dense type of disaggregates at city level
Periodicity of data availability and census data resolution	Build capacities at National levels to ensure data is regularly updated and at the required resolution

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