Regional Workshop on Data Capturing Methods ad Reporting of Human Settlement Indicators in Arab Countries

Use of GIS in Measuring Human Settlement Indicators

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3 – 5 July 2018
Cairo, Egypt
GIS in the SDG 11 Monitoring Framework

- All indicators are connected to space, but some require direct spatial measurement

- In SDG 11 ..... 
  - Locational attributes affect results in at least 8 indicators – 11.1.1, 11.2.1, 11.3.1, 11.5.1, 11.5.2, 11.6.1, 11.6.2, 1.7.1
  - At least 3 indicators require direct spatial data for measurement – 11.2.1, 11.3.1, 11.7.1
  - Characteristic specific estimates can be achieve for several other indicators – 11.1.1, 11.5.1,

- GIS in SDG 11 is needed to ..... 
  - Identify/ extract urban areas – functional city areas
  - Extract indicator specific information
  - Interface socio-demographic and economic data with space
  - Model urban systems
  - Multi-indicator and multi-temporal analysis and interpretation of data
  - Reporting and supporting informed decision making

What is GIS?
- Computer system
  - Hardware
  - Computer, plotter, printer, digitizer
  - Software and appropriate procedures
  - Spatially referenced or geographic data
  - People to carry out various management and analysis tasks
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Indicator 11.3.1 Land Consumption Rate to Population Growth Rate

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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

Tier II indicator
Outline

- Rationale for monitoring indicator
- Indicator components
- Definition of concepts
- Computation
Why monitor

• Need to understand how cities grow – is it just a factor of population?
  • Start answering some questions from CPI monitoring – why do some cities grow more sustainably than others?

• How does city growth affect regional development, policies, and actions? E.g sprawl and regional policies

• To understand “speed of transition” and where growth is happening spatially –
  • key components of urban challenges diagnosis and for making of informed decisions on both urban growth and development control.

• Majority of urban growth is happening in emerging small towns with populations of less than 500,000 people; big towns are also growing fast (UN-Habitat, 2010) – what kind of growth is this? Compact or dispersed?

• Informs investment – compactness versus dispersal have different investment implications

• Data will help development of practical international guidelines, that are locally applicable

• Data will help monitor vulnerability and appropriately prepare for disaster response - such as urban disasters related to rapid settlement in environmentally sensitive areas.

• Understanding land consumption cultures (historical) inform spatial planning, help protect environmental, social and economic resources and help project land demand for urban growth.
Indicator Components and Reporting

- **Land consumption rate** – the annual rate at which cities uptake land for urbanized uses (both built-up and open space demands)

- **Population growth rate** - the change in population in a given area over a unit period of time; expressed as a percentage of the number of individuals in the population at the beginning of that period

**Reporting**

- Monitoring to be repeated at regular intervals of 5 years
- Data collection will be at the city level, which will be used to develop national, regional, global aggregates
Cities consume land in multiple ways as they grow
Definition of concepts

- **City** – the urban extent as defined by the functional, spatially delimited boundaries
- **Built up area** – the contiguous part of a city occupied by buildings and other impervious surfaces
- **Non-built up area** – the part of a city that is not occupied by buildings and other impervious surfaces. This includes subdivided and non-divided land, public spaces, developable and undevelopable land within the city limits.
Some Data Sources for Indicator Computation

• National Statistical Agencies
  • Custodians of statistical data in countries - Source of population data (incl. high resolution mapped data)
  • Reference authority for data disaggregation, interpolation/extrapolation

• UNDESA - Global Urbanization Prospects initiative.

• City/ country high resolution imagery
  • Country based sensors ; High resolution commercial imagery through partnership with providers
  • The preferred option for indicator computation – where they exist

• Open source Imagery Platforms
  • Landsat – NASA; 16 days return period ; average 30m spatial resolution
  • Sentinel 2– European Space Agency ; 5 day return period, average 20m spatial resolution
  • Google Earth –medium to high resolution free imagery

• Analytical databases
  • Global Human Settlements Layer (GHSL), EC/JRC varied data from 1975 – 2015
  • Atlas of urban expansion, NYU, UN-Habitat, Lincoln Institute
  • Global Urban Footprint (German Aerospace Center) -
  • Gridded Population of the World (GPW)
  • Degree of Urbanization Global Human Settlement Grid

Most open source platforms offer good starting point where data is inexistent
Generic steps for current method

- Decide the two years for which the indicator should be computed – usually, 5 to 10 year intervals
- Using spatial metrics, delimit urban extent for the two years – which is a factor of built up areas and urbanized open spaces = functional city boundary for year x, y
- Collect/generate population data for each of the years – interpolate/extrapolate to year and functional city boundary
- Compute indicator

- Example application:
  - Ho Chi Minh City, Vietnam
Step 1: Delimit functional city area

1. Download imagery from USGS, Sentinel or use high resolution city/country imagery

2. Undertake supervised imagery classification in image processing/GIS software – classes can include built-up areas, open spaces, water etc

3. Undertake spatial statistics analysis to distinguish between urban and rural pixels

4. Buffer urban pixels to 100m to attain fringe open space area

5. Gap fill to attain continuous urban boundary and compute area using geometry tools in GIS or alternative statistical methods
Step 2: Collect/Generate population data

- Population growth rate may be easier to measure from years’ of experience and monitoring. General formula applies

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

- But how do we **disaggregate population** where a spatially functional city boundary partially includes an Enumeration area?
  - Preferred method is **to re-compute population using household level data (e.g. Egypt)**, but this may not always be possible in all countries
  - Other options
    - **Building**
      - **Population density for EA** - which is multiplied by land area of “included” part of EA
      - **Built-up pixel density for EA** – which is multiplied by number of built-up pixels in “included” part of EA
    - Built-up pixels helps redistribute population based on settled areas but does not account for built-up land use variations
Spatial disaggregation of population data

Proposed approach on spatial disaggregation of population:

- Using Enumeration areas as defined by NSAs
- Calculate area covered by Built-up pixels within EA
- Divide EA population by built-up area = \( \frac{\text{No. of people}}{\text{Built-up pixel}} \)
- Multiply built up density by partial EA size to attain population
Step 3: Compute Indicator

Compute Land consumption rate for years A - B

\[
LCR = \frac{\ln(Urb_{t+n}/Urb_t)}{y}
\]

Where

- \(Urb_t\) Urban extent in km² for the initial year
- \(Urb_{t+n}\) Urban extent in km² for current year
- \(y\) number of years between the two measurement periods

Compute Population Growth Rate (PGR) for years A - B

\[
PGR = \frac{\ln(Pop_{t+n}/Pop_t)}{y}
\]

Where

- \(Pop_t\) Total population within the urban extent in initial year
- \(Pop_{t+n}\) Total population within the urban extent current year
- \(y\) Number of years between the two measurement periods

Compute the ratio of land consumption rate to population growth rate (LCRPGR)

\[
LCRPGR = \left(\frac{\text{Annual Land Consumption rate}}{\text{Annual Population growth rate}}\right)
\]

Thus

\[
LCRPGR = \frac{\left(\frac{\ln(Urb_{t+n}/Urb_t)}{y}\right)}{\left(\frac{\ln(Pop_{t+n}/Pop_t)}{y}\right)}
\]
Methodological limitations

• Approach to land consumption concept is too simplistic for actual urban growth dynamics (internal reflections)

• Approach captures only the urban extent change, nothing on internal city dynamics which is critical to urban decision making
  • How do we know when cities lose some of their area due to disasters, natural catastrophes? (Corbane et al, 2017)
  • Cities grow in multiple ways, why capture only one?
    • Infill - built-up areas added during a growth period that occupy urbanized open space within the urban extent of the earlier year
    • Extension - built up areas added during the growth period that constitute contiguous urban clusters that are attached to the urban extent in the earlier period
    • Leapfrogging - built up areas added in the new period that constitute new contiguous urban clusters that are not attached to the urban extent of the earlier period
    • Inclusion covers the added areas that existed at the previous time period but were outside the urban extent of that period. (do not constitute new development)
Considerations to report on both outwards and internal city growth

- Measure the amount of land consumed by outwards city expansion between years
- Measure amount of land consumed by internal city growth between years

Outwards growth measures both newly built areas and open spaces as defined by urban extent.

Internal growth measures change of land from open space to built up within the same boundaries. E.g., replacement of open spaces by buildings, or vice versa – it's important to understand intra-city growth dynamics.

**Compute Land consumption rate between target years**

\[
\text{Outwards LCR} = \frac{\ln\left(\frac{\text{Urb}_{t+n}}{\text{Urb}_t}\right)}{y}
\]

\[
\text{Internal LCR} = \frac{\ln\left(\frac{\text{Bu}_{t+n}}{\text{Bu}_t}\right)}{y}
\]

**Where**

- \(\text{Urb}_t\) Urban extent in km² for the initial year
- \(\text{Urb}_{t+n}\) Urban extent in km² for current year
- \(y\) Number of years between the two measurement periods
- \(\text{Bu}_t\) Built up area in km² for the initial year
- \(\text{Bu}_{t+n}\) Built up area in km² for the current year
COMPUTATION APPLICATION

HO CHI MINH CITY, VIETNAM

Computation Years: 1989 – 1999
1999- 2015
Calculation: External Growth

Urban extent size (Sq.Km)

- 1989 = 84.537
- 1999 = 224.883
- 2015 = 1037.286

LCR from external growth

\[ LN\left(\frac{\text{Urb}_{t+n}}{\text{Urb}_t}\right) \] (y)

<table>
<thead>
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<th></th>
<th>1989</th>
<th>1999</th>
<th>2015</th>
<th>LCR URBAN EXTENT</th>
<th>LCR/PGR</th>
<th>URBAN EXTENT ONLY</th>
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<tr>
<td>Urban extent</td>
<td>84.537</td>
<td>224.883</td>
<td>1037.286</td>
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<tr>
<td>Built up</td>
<td>53.7768</td>
<td>77.1615</td>
<td>79.9101</td>
<td>0.097839</td>
<td>0.095549</td>
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<td>3,950,264</td>
<td>10,187,671</td>
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</tr>
<tr>
<td>LCR/PGR</td>
<td>1989-1999</td>
<td>1999-2015</td>
<td></td>
<td>2.3</td>
<td>1.6</td>
<td></td>
</tr>
</tbody>
</table>
Calculation: Internal Growth

Built Up Area 1989 = 53.7768

Built Up Area 1999 = 77.1615

Built Up Area 2015 = 79.9101

Urban extent Area (fixed boundary) 1989

Internal LCR = \[
\frac{\ln((BU_{t+n}/BU_t))}{(\gamma)}
\]
What do the numbers mean?

- Value of 1 for outwards LCR – cities are consuming land at the same rate as population (might be ideal though lower values in well planned areas better)
- Above 1: Faster growth of land consumption than population
- Below 1: Faster population growth than city land uptake

Linkage between land and population creates a new level of interesting data to aid urban management
Limitations

- Importance of indicator to cities
  - Indicator is a good basis for understanding local urbanization trends
- Capacity to compute indicator at country level
- High variations in cities growth patterns – requiring multiple actions / policies to address various urbanization trends
- Lack of high resolution population data and poor data sharing culture among government actors

Opportunities

- Indicator has long term value that is of interest to cities
  - Modeling of growth can help city predict future growth
- Presence of large databases and datasets to help compute indicator
THANK YOU

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