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MONITORING URBAN EXPANSION USING REMOTE SENSING AND
A NETWORK OF CITY-BASED RESEARCHERS¹

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A. INTRODUCTION

The Urbanization Project—the movement of people from village to cities and towns—began in earnest in 1800, when less than 10 per cent of the planet’s population lived in cities. It reached a peak in 2000 when half the world’s urban population lived in cities and the world’s urban growth rate began to slow down. Urbanization is likely to come to an end by 2100, when the world’s population growth is expected to come to a halt and when as many as three quarters of the world’s population will live in cities. In a short span of 12 generations, humanity as a whole has consciously decided that living closer to one another is preferable to living closer to the land, and has acted—and is still acting—quite emphatically on that decision. The coming decades thus offer a window of opportunity, short as it may be, to make minimal preparations for the coming urban population growth and its concomitant urban expansion. Romantic as it may seem to some, efficient, equitable and sustainable cities are not self-organizing. They do not come about as a result of the spontaneous actions of the multitudes of individuals, groups or firms. They come about as a result of these multitudes acting in unison as a *public* to lay out areas of expansion in an orderly, efficient, equitable and sustainable manner before they are occupied: reserving adequate lands for public works and public open spaces in advance of the construction of homes, workplaces and public facilities on the remaining lands.

By now, it should already be abundantly clear that there is no hope in slowing down the urbanization process or in shifting populations among cities. People are free to move within their own countries and their right to move is enshrined in the *Universal Declaration of Human Rights*.¹ Population growth in cities large and small, as is known, cannot be effectively guided by policy. But the conversion of land from rural to urban use is very much guided and influenced by policy.

Empirical data on actual urban expansion and its key attributes in many cities around the world, over long periods of time, can provide a much-needed basis for understanding the global and historical contexts of urban expansion. Coupled with theories that could explain the underlying forces that propel and shape urban expansion, these data could provide the evidence needed to assess and address our concerns that it would be very difficult, if not futile, to resist urban expansion in the face of rapid population growth. Ignoring it or denying it in the hope that it will not occur will simply allow it to take place unhindered and in a more costly and destructive way. Acquiring a better understanding of it will make it less formidable and more manageable and making minimal yet effective preparations for it is the right way and certainly the only responsible way, to proceed.

B. THE CITY AS A UNIT OF ANALYSIS AND THE UNIVERSE OF CITIES

Monitoring efforts are focused on cities of 100,000 people or more. Different countries have adopted different thresholds for a human settlement to be considered a ‘city’, but there is near universal

¹ UN General Assembly, *Universal Declaration of Human Rights, Article 13*, 10 December 1948, 217 A (III), Available from <http://www.un.org/en/documents/udhr/> [accessed 13 August 2015].

agreement² that a settlement of 100,000 people or more constitutes a city. Attention is also focused on entire metropolitan areas: contiguous urban areas that may contain many municipalities are considered to be a single city.³

Cities are defined by the extent of their built-up area, rather than by their administrative or jurisdictional boundaries. The *extrema tectorum*—the limit of the built-up area of the city, as it was referred to in Ancient Rome—defines the city and the city thus defined is our unit of analysis.⁴ Some 4,245 cities have been identified on our planet that are homes to 100,000 people or more in 2010. These 4,245 cities constitute our *Universe of Cities* (see figure 1). The total 2010 population of this universe of cities amounted to 2.5 billion or 70 per cent of the world's 2010 urban population of 3.6 billion.⁵ The remaining urban population lived in cities and towns that had less than 100,000 people.

It is important to note that three quarters of the cities in the universe of cities are in developing countries. More precisely, 3,130 cities out of the total 4,245 (74 per cent), housing 1.85 billion people out of a total 2.5 billion (also 74 per cent) are in developing countries. The share of projected urban population growth in coming decades in developing countries is much greater. Between 2015 and 2050, the world's urban population is now expected to increase by 2.38 billion people.⁶ Only 5 per cent of that increase (130 million) will be in developed countries. The rest, 95 per cent or 2.25 billion, will be in developing countries. In other words, the increase in the city populations in developing countries will be 18 times that of the increase in the city populations of developed countries. This urban growth in the coming decades is a challenge for city planners, municipal officials, central government officials, international organizations, civic sector leaders, students of cities and interested citizens in developing countries, not for cities in developed countries. These cities, on the whole, have fewer fiscal resources, weaker rule of law, higher levels of corruption and less experienced public servants, but also higher built-up area densities, more reliance on public transport, and lower levels of energy use. It may well be that the urbanization agenda for developing-country cities may be quite different than the urbanization agenda of developed-country ones. Still, from the point of view of monitoring urbanization in general and urban expansion in particular, it is important to study both developed-country cities and developing-country cities using the same conceptual framework and the same methods for data collection and analysis.

1. *The global sample of cities*

The universe of cities can be studied by examining a carefully selected sample from this universe, selected with a view to obtaining results that can be generalized to the entire universe. A stratified global sample of 200 cities, roughly 5 per cent (4.7 per cent) of the 4,245 cities in the universe in 2010 has been selected (see figure 2 and table 1).

² With the important exception of China where there were only 657 officially designated cities in 2015, where there were hundreds of settlements of 100,000 people or more that we have counted as cities.

³ There are a few exceptions to this convention. In countries where many large cities have combined to create elongated conurbations that stretch for hundreds of kilometers—for example, the Northeast cities in the United States or the Rhein-Ruhr cities in Germany—we have separated the major cities along administrative boundaries. We have also adopted a formula for the inclusion of towns that are not contiguous to large urban agglomerations, where the distance to the agglomeration is a function of its area.

⁴ The populations of cities are, and should, be calculated using data on the populations of the administrative districts containing the built-up areas of these cities. Where these administrative units are large and contain other built-up areas that are not part of the city, we allocate a population to the city that is equivalent to its share of the built-up area within the set of administrative districts containing its built-up area.

⁵ United Nations, Department of Social and Economic Affairs, Population Division 2014, File 3: Urban Population at Mid-Year by Major Area, Region and Country, 1950-2050 (thousands), available at: <http://esa.un.org/unpd/wup/CD-ROM/> [accessed August 13, 2015].

⁶ *Ibid.*

Table 1. A comparison of the universe of cities and the sample of cities, stratified according to regions, city population groups and number of cities per country categories

| Regions | Universe | | | | Sample | | | |
|---|------------------|--------------|------------------------|--------------|------------------|--------------|----------------------|--------------|
| | Number of Cities | % of total | Total Urban Population | % of total | Number of Cities | % of total | Population in Sample | % of total |
| East Asia and the Pacific (EAP) | 1,089 | 26.0 | 645,356,592 | 26.0 | 42 | 21.0 | 154,459,839 | 21.0 |
| Southeast Asia (SEA) | 232 | 5.0 | 128,492,546 | 5.0 | 15 | 8.0 | 37,995,438 | 5.0 |
| South and Central Asia (SCA) | 693 | 16.0 | 392,876,899 | 16.0 | 32 | 16.0 | 121,380,230 | 17.0 |
| Western Asia and North Africa (WANA) | 300 | 7.0 | 180,525,762 | 7.0 | 15 | 8.0 | 62,177,236 | 9.0 |
| Sub-Saharan Africa (SSA) | 331 | 8.0 | 186,626,671 | 7.0 | 18 | 9.0 | 50,018,112 | 7.0 |
| Europe and Japan (E&J) | 781 | 18.0 | 396,157,559 | 16.0 | 34 | 17.0 | 127,216,190 | 18.0 |
| Land-Rich Developed Countries (LRDC) | 334 | 8.0 | 240,725,842 | 10.0 | 18 | 9.0 | 68,421,847 | 9.0 |
| Latin America and the Caribbean (LAC) | 485 | 11.0 | 320,102,523 | 13.0 | 26 | 13.0 | 98,805,345 | 14.0 |
| Grand Total | 4,245 | 100.0 | 2,490,864,393 | 100.0 | 200 | 100.0 | 720,474,238 | 100.0 |
| City Population Groups | Universe | | | | Sample | | | |
| | Number of Cities | % of total | Total Urban Population | % of total | Number of Cities | % of total | Population in Sample | % of total |
| 100,000 - 425,677 | 3,150 | 74.0 | 622,400,949 | 25.0 | 56 | 28.0 | 12,585,331 | 2.0 |
| 425,678 - 1,559,789 | 814 | 19.0 | 622,296,461 | 25.0 | 50 | 25.0 | 41,719,128 | 6.0 |
| 1,561,742 - 5,556,200 | 227 | 5.0 | 619,845,757 | 25.0 | 54 | 27.0 | 171,482,632 | 24.0 |
| 5,718,232 + | 54 | 1.0 | 626,321,226 | 25.0 | 40 | 20.0 | 494,687,146 | 69.0 |
| Grand Total | 4,245 | 100.0 | 2,490,864,393 | 100.0 | 200 | 100.0 | 720,474,238 | 100.0 |
| Number of cities per Country Categories | Universe | | | | Sample | | | |
| | Number of Cities | % of total | Total Urban Population | % of total | Number of Cities | % of total | Population in Sample | % of total |
| 1-9 | 370 | 9.0 | 184,155,422 | 7.0 | 23 | 12.0 | 39,166,655 | 5.0 |
| 10-19 | 307 | 7.0 | 154,896,704 | 6.0 | 18 | 9.0 | 35,382,060 | 5.0 |
| 20 + | 3,568 | 84.0 | 2,151,812,267 | 86.0 | 159 | 80.0 | 645,925,523 | 90.0 |
| Grand Total | 4,245 | 100.0 | 2,490,864,393 | 100.0 | 200 | 100.0 | 720,474,238 | 100.0 |

Source: Angel, Shlomo and others (2015).

The sample was selected with three criteria in mind: (1) selecting cities from eight world regions, in proportion to the urban population in each region; (2) one fourth of the cities must be drawn from four population-size categories, each category containing a quarter of the total population of the cities in the universe; and (3) selecting cities from three country categories—those with 1-9 cities, those with 10-19 cities, and those with 20 or more cities with a slight bias towards the first two categories (e.g., only 9 per cent of the cities in the universe but 12 per cent of the cities in the sample are in countries with 1-9 cities).

The division of the world into regions largely follows that of the United Nations with a few important differences. First, Western Asia and Northern Africa were unified into one region. Second, Japan was included in Europe, largely because of its similar levels of urbanization and development. Third, the United States, Canada, Australia and New Zealand were grouped into a region entitled *Land-*

Rich Developed Countries. All have large agricultural hinterlands and their cities have large expanses of low-density suburban developments that distinguish them from European or Japanese cities.

It is also important to note that the second criterion—dividing the cities into four population size groups, each containing the same total population—biases the sample toward larger cities. The four population size groups contain the same total population, but there are as many as 3,150 cities in the first group (100,000-425,000) and 56 of them are in the sample, but there are only 54 cities in the fourth population size group (5.6 million plus) and 40 of them are in the sample. As a result, the 200 sample cities constitute only 4.7 per cent of the number of cities in the universe, but have a population of 720 million, 29 per cent of the total population of the universe. Data on the universe and the sample is given in table 1.

The representativeness of the sample was tested in the following manner: knowledge of the 2000-2010 population growth rates of all cities, both the cities in the universe and the cities in the sample; comparison of their averages was done—both weighted and un-weighted—and found that they were not statistically different from each other at the 95 per cent confidence level. That being said, there were still last minute changes in the sample and—as a consequence—in the universe of cities as well.

The results of the analysis of satellite imagery, in conjunction with the population data associated with administrative districts, sometimes reveal that (1) a city that may have been on its own in earlier periods is now included in a larger metropolitan area; or (2) that although its administrative district contains more than 100,000 people, the built-up area associated with the city contains less than 100,000 people. In both cases, this city was replaced with a new city selected at random from the same regional, city size, and the number of cities in the country grouping.

C. MONITORING GLOBAL URBAN EXPANSION

The NYU Urban Expansion Program—supported by the NYU Stern Urbanization Project and the NYU Marron Institute of Urban Management, in partnership with the United Nations Human Settlements Programme (UN Habitat) and the Lincoln Institute of Land Policy—has initiated a multi-phase research effort to monitor the quantitative and qualitative aspects of global urban expansion. This effort is a continuation of an earlier project by the authors and their colleagues that resulted in the *Atlas of Urban Expansion* (Cambridge MA: Lincoln Institute of Land Policy, 2012). The monitoring program now has four interdependent phases in different stages:

Phase I: *The Mapping & Measurement of Global Urban Expansion*, focuses on the mapping and measurement of key *attributes* of global urban expansion—urban extent, average built-up area density, the fragmentation of the built-up area of the city by open spaces, and the compactness of the shape of city footprints—in the global sample of 200 cities in three time periods: Circa 1990, circa 2000, and circa 2014. This phase requires the classification and analysis of medium-resolution *Landsat* satellite imagery as well as census data associated with administrative districts that contain the built-up areas of these cities.

The maps and metrics for a new global sample of 200 cities for three time periods—circa 1990, circa 2000 and circa 2014—will be available in the forthcoming *Atlas of Urban Expansion—The 2015 Edition* (Angel and others, NYU, UN Habitat and Lincoln Institute 2015), to be published online in the fall of 2015. Preliminary results for one third of the cities in the new sample, results that still need to be checked, suggest that the average densities of the built-up areas of cities continued to decline—at a rate significantly different from 0 at the 95 per cent confidence level—in the period 2000-2014.

Phase II: *The Mapping and Measurement of Urban Layouts*, focuses on (1) how well laid out are recently-built urban peripheries (areas built between 1990 and 2014) in the global sample of 200 cities; (2) how well laid out are urban areas built before 1990 compared to areas built between 1990 and 2014 in the global sample of 200 cities; and (3) how well laid out are city areas built in five different time periods—before 1900, between 1900 and 1930, between 1930 and 1960, between 1960 and 1990, and between 1990 and 2014—in a representative sample of 30 cities.

Very little is known about the peripheries of our cities, the vast areas where urban expansion is now taking place. Ill understood and disorganized as it may be, land on the urban fringe is being transferred and put to urban use one way or another at a rapid rate, a rate commensurate with the pace of population growth and economic development in the city. Once land is transferred to urban use and to urban users, its character changes. Phase II of the monitoring effort seeks to fill this important gap in our understanding of cities. Focusing on urban peripheries built during the last two decades in a global sample of 200 cities, the attributes were measured in a randomly chosen set of 10-hectare locales in each urban periphery using high-resolution *Bing* and *Google Earth* satellite imagery. In parallel, access to arterial roads were measured—the density of arterial roads and the average beeline distance to an arterial road—in the expansion area as a whole.

Data on urban layouts in cities the world over is beginning to emerge for the first time. A superficial examination of these data suggests that urban peripheries in cities of the world are not being developed in an efficient, equitable and sustainable manner. That being said, the full data set, soon to be completed, for all 200 cities in the sample will be used to begin to understand the scope of the problem and to begin to chart effective paths for solving it, or at the very least ameliorating it in the coming years.

Phase III: The mapping and measurement of actual urban layouts in the expansion areas of the 200 cities in the global sample will provide us, for the first time, with an accurate picture of conditions on the ground in these cities at the present time. But it will not tell us much about why these conditions prevail, or what the consequences of these conditions are for the people that have to confront them, the households that must find homes and the businesses and services that must locate in the new expansion areas of cities. Phase III of monitoring global urban expansion—*the Land and Housing Survey in a Global Sample of Cities*—seeks preliminary answers to these questions.

The Land and Housing Survey includes two separate surveys. The first, *the Regulatory Survey*, seeks to obtain information on land ownership patterns on the urban fringe, land transactions and respect for property rights; the practice of government land expropriation: land invasions and their handling by authorities; land-use planning and the presence of restrictions on the conversion of lands from rural to urban use; the responsibility for street layouts; the effectiveness of key land subdivision regulations; minimum lot size and minimum street width; height and density restrictions; and barriers to densification.

The second, *The Affordability Survey*, seeks to obtain information on the range of prices and rents as well as the key attributes of different types of residential plots and dwelling units in the city: building plots in formal and informal land subdivisions; land-and-house packages; apartments; and plots in squatter settlements. It also seeks information on the time of travel during rush hour by car, by two-wheelers, and by public transport—as well as the cost of travel by public transport—from four key locations on the urban periphery to the center of the city.

Researchers have been contracted to complete the surveys in their cities. Initial results are expected early in the fall of 2016 and the survey should be completed by mid-2016, in time for Habitat III, the United Nations Conference on Housing and Sustainable Urban Development, to be held in the fall of 2016.

REFERENCE

Angel, Shlomo and others (2015). Monitoring the quantity and quality of Global urban expansion. NYU Marron Institute of Urban Management Working Paper No.24 (September 2015).