



HAL
open science

More Urban Constructions for Whom? Drivers of Urban Built-Up Expansion Across the World from 1990 to 2015

Eric Denis

► **To cite this version:**

Eric Denis. More Urban Constructions for Whom? Drivers of Urban Built-Up Expansion Across the World from 1990 to 2015. Pumain Denise. Theories and Models of Urbanization, Theories and Models of Urbanization, Springer, pp.235-258, 2020, Lecture Notes in Morphogenesis, 978-3-030-36655-1. 10.1007/978-3-030-36656-8_13 . hal-02430053

HAL Id: hal-02430053

<https://hal.science/hal-02430053v1>

Submitted on 22 Aug 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Metadata of the chapter that will be visualized in SpringerLink

Book Title	Theories and Models of Urbanization	
Series Title		
Chapter Title	More Urban Constructions for Whom? Drivers of Urban Built-Up Expansion Across the World from 1990 to 2015	
Copyright Year	2020	
Copyright HolderName	Springer Nature Switzerland AG	
Corresponding Author	Family Name	Denis
	Particle	
	Given Name	Eric
	Prefix	
	Suffix	
	Role	
	Division	
	Organization	CNRS, UMR Géographie-Cités
	Address	Paris, France
	Email	eric.denis@parisgeo.cnrs.fr

Abstract	<p>Since the 1990s, the conversion of land for urban use has never been more intense. Occurring under all latitudes, transcending the economic disparities as well as the political regimes, urban built-up expansion appears very much articulated to the global financial turn, which occurred after the progressive destatization of the money creation, which accelerated and globalized after the debt crisis of the 1980s. Using the Global Human Settlement Layer dataset on the degree of urbanization, we can assess that, worldwide, the built-up surface expanded by 243,000 km² between 1990 and 2015 and the average urban density has declined slightly from 2775 inhabitants per km² to 2756. After describing the national level dataset used and our methodology, we expose the regional nuances in the global built-up spreading and their relations to population growth. Then in a third section, we correlate those national trends with a set of significant economic indicators. We articulate it also to the individualization and progress of housing condition. Population growth remains the dominant factor determining urban built-up spread, but countries differ. Built-up growth did not respond linearly to the final demand for housing and therefore to demographic pressure. Building is a material good whose value is also interdependent with economic growth. The universal relationship between size and density specific to scaling laws is verified once again in the case of cities. However, economic density or concentration of wealth tends to take precedence over population mass to explain urban built-up expansion.</p>
----------	--

Chapter 13

More Urban Constructions for Whom? Drivers of Urban Built-Up Expansion Across the World from 1990 to 2015



Eric Denis

1 **Abstract** Since the 1990s, the conversion of land for urban use has never been
 2 more intense. Occurring under all latitudes, transcending the economic disparities
 3 as well as the political regimes, urban built-up expansion appears very much articu-
 4 lated to the global financial turn, which occurred after the progressive destatization
 5 of the money creation, which accelerated and globalized after the debt crisis of the
 6 1980s. Using the Global Human Settlement Layer dataset on the degree of urbaniza-
 7 tion, we can assess that, worldwide, the built-up surface expanded by 243,000 km²
 8 between 1990 and 2015 and the average urban density has declined slightly from
 9 2775 inhabitants per km² to 2756. After describing the national level dataset used and
 10 our methodology, we expose the regional nuances in the global built-up spreading
 11 and their relations to population growth. Then in a third section, we correlate those
 12 national trends with a set of significant economic indicators. We articulate it also to
 13 the individualization and progress of housing condition. Population growth remains
 14 the dominant factor determining urban built-up spread, but countries differ. Built-
 15 up growth did not respond linearly to the final demand for housing and therefore
 16 to demographic pressure. Building is a material good whose value is also interde-
 17 pendent with economic growth. The universal relationship between size and density
 18 specific to scaling laws is verified once again in the case of cities. However, economic
 19 density or concentration of wealth tends to take precedence over population mass to
 20 explain urban built-up expansion.

21 13.1 Introduction/Facts and Hypothesis

22 The conversion of land for urban use has never been more intense than it has been
 23 since the 1990s. Occurring under all the latitude, transcending the economic dis-
 24 parities as well the political regimes, urban built-up expansion appears very much
 25 articulated to the global financial turn, which occurred after the progressive destati-
 26 zation of the money creation, which accelerates and globalized after the debt crisis of

E. Denis (✉)
 CNRS, UMR Géographie-Cités, Paris, France
 e-mail: eric.denis@parisgeo.cnrs.fr

© Springer Nature Switzerland AG 2020
 D. Pumain (ed.), *Theories and Models of Urbanization*, Lecture Notes
 in Morphogenesis, https://doi.org/10.1007/978-3-030-36656-8_13

1

27 the 1980. Deregulation lead to a tremendous expansion of credit but also to a chronic
 28 financial instability. Land and real estate becomes, in that context, a banking asset
 29 supporting a speculative rise of money creation widely disconnected of the produc-
 30 tive machine needs. Hence, land driven development becomes a major motor engine
 31 of growth in many countries, in particular for the transitional economies. With gold,
 32 land constitutes one of the last warranties for the money creation. Land at the edge
 33 of cities represents also a frontier of non-fungible value to conquer and to introduce
 34 to the urban market and convert to private and fungible wealth. Conversion of land
 35 to urban uses is not the simple support of economic growth, it constitutes a major
 36 component of it, including the response to the need of productive spaces (for indus-
 37 tries, offices, trades and logistic platforms) as well for housing and for, an expanding
 38 part, as a financial asset.

39 The de-densification and sprawl, is also the complex product of two structural
 40 changes: the parental de-cohabitation and the increase of standard of living. Chil-
 41 dren no longer stay in their parents' home at the time of marriage and houses and
 42 apartments tend globally to become larger. In other words, the structural and acceler-
 43 ated decline of density has to do with the dynamic of individualization, nuclearisation
 44 of families, as well the aspiration to individual bedrooms for kids. The habitation
 45 households claim to settle in tend to enlarge and the desire for individual housing
 46 becomes more and more a shared dream. The economy founds new opportunities in
 47 these personalizing trends when people are less bound in local solidarity group. They
 48 become more dependent of services to assist and eventually stimulate and create their
 49 growing individual aspirations.

50 Sprawl is a multidimensional phenomenon that could not be precisely evaluated
 51 using the set of data aggregated at the level of country we use.¹ Only the relation
 52 between density and growth of the built-up gives us here an indication of the urban
 53 trend. In our chapter, sprawl is viewed as the combination of the intensity of the
 54 relation between population density decline and increase of construction footprint.

55 Two global dependent indicators highlight our assumption: first-of-all, worldwide,
 56 the built-up surface expanded by 243,000 km² between 1990 and 2015, almost the
 57 full area of the United Kingdom; secondly, the average urban density (cities, suburbs
 58 and urban clusters) has declined slightly from 2775 inhabitants by km² to 2756. The
 59 Global Human Settlement Layer (GHSL) Degree of Urbanization 2018 geodatabase
 60 analysis confirms what Seto et al. (2011) or Angel et al. (2015) highlighted using a
 61 vast sample of cities across the world.

¹Thanks to Thomas Kemper and Michele Melchiorri for pointing to me, reading this paper draft that it is difficult to assess precisely in what extend the urban built-up expansion contributes to the densification of existing urban perimeters and what is related to sprawl (expansion of the urban perimeters with low density). A key publication on sprawl (Tikoudis et al. 2018) points to the complex apprehension of sprawl that we cannot assess precisely with the summary country tables. A paper to come will precise further the extent of the sprawl using the detailed data per city and the gridded data. It requests to mobilize data to quantify the fragmentation vs. compactness of urban perimeters, the number of population centres (high density and polycentricity) and the share of urban population in low-density area.

62 The built up annual growth is globally faster than the demographic one, by a
63 factor of 1.17 between 1990 and 2000 and 1.13 between 2000 and 2015. The built
64 up annual growth was established at 1.69% during the first phase and 1.39% during
65 the second.

66 In the same time, between 1995 and 2014, global wealth grew by 66%, when the
67 GDP at constant price of 2010 almost doubles, from 44.9 to 77.6 trillion. This global
68 enrichment is materializing in the extension of the urban footprint. Furthermore,
69 this capitalization in land and building assets is a major driver of the global wealth
70 expansion. The total population grew only by 28% during the same period.

71 Our analysis confirms the strong correlation between urban built-up footprint
72 distribution (log) by country and population (log); established at 0.88 in 2015.² They
73 are definitively intricate grandeurs as are logs of GDP and built-up ($R = 0.55$).
74 Richest countries have a more extended urban footprint. After Henderson (2003), it
75 confirms the canonical and strong relation between logs of GDP per capita and share
76 of urban population ($R = 0.85$) but population demand matters.

77 Based on the Degree of Urbanisation Model (DEGURBA) developed in the frame
78 of the “Global Human Settlement Layer” (GHSL) project of the European Commis-
79 sion’s Joint Research Centre, in 2015, 84% of the world population live in areas
80 covered of continuous built-up at 50%, or cities plus suburbs and urban clusters. In
81 other words, in densely inhabited areas and intermediate density areas, using a 1
82 square kilometre grid to articulate built-up footprint and population, as we will detail
83 it in the following methodological section.

84 We should here relativize the pace of the built-up sprawl, in the sense that the urban
85 agglomeration remains the most efficient way to use the terrestrial surfaces and to
86 accommodate more than 7 billion inhabitants and most of their productive activi-
87 ties and daily commuting. All the negative externalities associated to agglomeration,
88 notably congestion and pollution can be deeply mitigated using the present technolo-
89 gies and implementing appropriate rule of law. In fact, the total built-up spreads only
90 on 0.6% of the terrestrial surfaces. The agglomeration process is not negative in itself.
91 Even if we consider only the ecumene out of the land mass belonging to countries,
92 it did not reach 1%. It occupies 1.7% of the land mass and 2.7% of the ecumene, if
93 we consider the 1 km² grid where population and built-up information are merged in
94 the “Degree of urbanisation” (DEGURBA) model and dataset (Dijkstra et al. 2018).
95 Nevertheless, de-densification of urban environment characterizes the current trend.
96 It leads to an extensive soil conversion.

97 In order to expose in detail and correlate precisely the global trend of built-up
98 expansion we are highlighting here, in a first section we describe the national level
99 dataset used and our methodology. Then, in a second section, we expose the regional
100 nuances in the global built-up spreading and their relations to population growth. In
101 a third section, we correlate those national trends with a set of significant economic
102 indicators, such as the share of fix capital and labour, FDI, cement production, share

²We should consider here that the two variables, built-up and population are not fully independent. The estimated population within agglomerate is evaluated in relation with the density of built-up in 1 by 1 km² grid.

103 of construction sector in GDP. We articulate it also to the individualization and
 104 progress of housing condition. In conclusion, we expose some element related to the
 105 multiplication of localities and its consequence on urban hierarchies showing that,
 106 beside the expansion of urban units and mega urban region formation, we have to
 107 consider the less visible process of small towns' emergence.

108 **13.2 A New Information Source on Global Urbanization**

109 Measuring urbanization at the world scale was until recently almost impossible. We
 110 were comparing very much different objects defined as urban units. There was no
 111 harmonised dataset overpassing the various national definitions of the urban sec-
 112 tor. The measurement of urbanization taking into account individual settlements and
 113 morphological agglomerations was until recently very rough and their spatial cov-
 114 erage was limited. Up to now, the most used datasets such as the UN-Habitat city
 115 population series are incomplete and biased by extremely heterogeneous definitions
 116 managed by independent administration of some 260 countries. François Moriconi-
 117 Ebrard (1993) demonstrated clearly the limitation of such series for a comparative
 118 study of urbanisation, generating major distortions. The international efforts of har-
 119 monization are yet very limited. Nevertheless, after Quito Habitat III Conference in
 120 2016 and the New Urban Agenda commitment, World Bank, OCDE and EU agreed
 121 to promote standard to generate harmonized geographical datasets. One of the major
 122 output is the development of an open source complete and multisource dataset sup-
 123 ported by Eurostat. Its fundamental concept is based on a three folds' definition
 124 recognising: (i) city, (ii) urban clusters and suburbs, and (iii) rural areas, villages or
 125 dispersed population. It distinguishes densely populated area, from intermediate and
 126 thinly populated areas³ (Dijkstra and Poelman 2014).

127 The dataset we use The Degree of Urbanisation from 1975 to 2015 last release
 128 2018 (DEGURBA 2018) appropriates this threefold definition. It constitutes a fun-
 129 damental output of The Global Human Settlement Layer project supported by the
 130 European Commission through the GEO Human Planet Initiative who generates
 131 it. It provides by countries and by morphological agglomerations multiple metrics
 132 described in Florczyk et al. (2018). It delineates precisely 10,322 urban centres
 133 (agglomerate units) between 50,000 inhabitants and 46 million in 2015 (Guangzhou
 134 in China). It is a unique source correlating population and build-up footprint. The
 135 Global Human Settlement built-up areas (GHS-BU) provides the concrete evidence
 136 of the presence of human concentration and their activities as demonstrated by Mel-
 137 chiorri et al (2018). The fundamental is to gather the tangible traces or observations
 138 of material transformation of the human environment—in other words, to detect and

³The only alternate yet promoted by EU and the OCDE after Quito Habitat is the Functional Urban Area (FUA) method. Previously known as larger urban zone (LUZ), it cumulates two major limitations that renders it inappropriate to conduct worldwide comparison: it details only the largest or metropolitan urban areas and it implies to gather harmonised data on daily commuting which are not available for many countries.

139 qualify the existence of built-up or building.⁴ A pure fact (the materiality of construction)
 140 (tion) grounds this approach of the urban. It is not in first instance supported by an
 141 institutional fact (administrative limit of city depending of human/social agreement).

142 The starting point is to consider, in order to achieve a unique instrument to measure
 143 the dynamic of settlement across the world, that only one approach can be used, based
 144 on the location of tangible footprint of human presence. It gathers two complementary
 145 gridded geographical layers: in one hand, the morphological spread of settlements
 146 using satellite imagery at 40 m resolution.⁵ The built-up grid gives a gradient of
 147 construction from zero to 98% based on the detection of constructions at 40 m.
 148 In a second hand, a population grid at 250 m resolution is generated using local
 149 population at municipal and district levels provided by censuses. Overlaying the two
 150 layers generalized in a 1 km² grid, it becomes possible to provide a harmonised and
 151 dynamic vision of the distribution of population articulated to the settlements they
 152 live in. The dataset is available for different dates: 1975, 1990, 2000, and 2015. This
 153 approach, based on mapping the territory through a grid, avoids distortions caused
 154 by using LAU2 or communes/municipalities varying tremendously in size and/or
 155 shape. Currently the GHSL-DEGURBA approach is certainly overestimating the
 156 urban population as it uses too aggregated data for population (mainly at district
 157 level) that are then too highly incorporated in urban.⁶

158 The 1975 GHSL assessment underestimates the existing built-up areas because of
 159 two main factors: (i) worse sensor characteristics, and (ii) the presence of large data
 160 gaps (no data available) in the 1975 collection. Mud and disperse type constructions
 161 are difficult to detect using 1975 satellite imageries. The underestimation is around
 162 20% globally, but it becomes extremely precise and comparable from 1990, with
 163 standardized observation and dataset in 2000 and 2016. Technical papers appreciate
 164 how the GHS-BU as well its one km² gridded overlaying generalization are consistent.
 165 GHS appears always equivalent or more precise than any other sources. It has

⁴The concept of “buildings” formalized by the GHSL are enclosed constructions above ground which are intended or used for the shelter of humans, animals, things or for the production of economic goods and that refer to any structure constructed or erected on its site (Pesaresi et al. 2013). For the GHSL concept, refugee camps, informal settlements, slums and other temporary settlements and shelters are included in the notion of built-up area.

⁵An open source automated processing workflow analyses an exhaustive global Landsat mosaic to provide a continuous built-up mosaic at 40 m resolution. It uses advanced automated machine learning and quality control comparing the results with existing open source layers such as MODIS, DMS/OLS night time lights, (Smith 2017) as well OpenStreet Map. Several researches assessed also the quality through comparison of various sources (Leyk et al. 2018; Lu et al. 2014). They validate that is the most advanced model of detection of built-up—errors are very limited. It is an open source in constant development, incorporating more and more advanced imageries, Sentinel in particular, and automated processes.

⁶Geopolis global database (<http://e-geopolis.org/>) is by far the most precise sources for a count of urban population by unit. Its unique methodology is taking into account the smallest census units, but the acquisition of built up footprints is dependent of human interpretation and scarcely updated. They cannot be used to conduct a precise work on built-up changes. In Geopolis, all the morphological agglomerations with more than 10,000 inhabitants are considered as urban. A morphological agglomeration is a built-up patch with less than 200 m between constructions (following UN recommendations). It uses open sources Google earth imagery.

166 been compared to the Gridded Population of the World, version 4.10 (GPWv4.10)²,
 167 the Global Urban Footprint (GUF) initiative (Esch et al. 2017), DMPS/OLS night
 168 light imagery (Li and Zhou 2017), as well the 30 m resolution global land cover
 169 (GlobeLand30) generated by Chun et al. (2014). Because of its multi-temporal avail-
 170 ability, it is achieving more than the Human Built-up and Settlement Extent at 30 m
 171 resolution too, but limited to a 2010 unique layer (HBASE; NASA-SEDAC).

13.3 Urban Expansion and Population

173 If urban morphological expansion is a global phenomenon, regional, national and
 174 local difference exists. They can be apprehended, first of all, in assessing the mate-
 175 rialization of new constructions using the 30 m resolution data, and secondly in
 176 appreciating the de-densification using the one km² gridded dataset.

177 In 2015, the urban built-up footprint occupies some 570,000 km² worldwide
 178 (Table 13.1). With 175,000 km² of constructions added since 1990, it expanded by
 179 some 44%. This spread equals the urban built-up of the whole Northern America in
 180 2015! The African continent experiment the most important expansion: there, the
 181 urban built-up almost doubled. In contrary, Europe experiment the slower built-up
 182 spread. Here appears that, at the macroscale, the physical expansion of the urban
 183 world is, in first instance, correlated to the demographic pressure (44% vs. 42). Nev-
 184 ertheless, the relation is not uniform; it differs from region to region. For instance, the
 185 European built-up expansion is, in fact, important vis-à-vis its population stagnation
 186 (18.5% vs. 1.6). Here it should be make clear that the built-up layer capture only
 187 the constructions. It ignore street networks and open spaces. It did not represent the
 188 entire urban perimeters. By coupling built-up and gridded population, as explained
 189 above, DEGURBA's approach provides a measure of functional urban perimeters.
 190 The urban built-up footprint is precisely the measure we are interested to study as

Table 13.1 Distribution of the urban built-up in square kilometres in 1990 and 2015, and changes

	Urban built-up			Variation 1990 to 2015		Urban population change
	1990	2000	2015	in km ²	in %	
World	394,842	465,745	569,942	175,099	44.3	42.2
Africa	32,826	43,230	62,138	29,312	89.3	101.7
Asia	138,813	171,802	226,471	87,658	63.1	39.5
Europe	100,075	108,485	118,627	18,552	18.5	1.6
Latin America and Car.	34,113	40,269	45,739	11,626	34.1	47.2
Northern America	81,555	93,809	107,888	26,333	32.3	35.8
Oceania	7470	8165	9097	1628	21.8	52.8

Source GHSL

191 a unique indicator of the dynamic of construction and investments driven towards
192 buildings.

193 Among 166 countries we consider here, twenty only contribute 74% of the built-
194 up expansion between 1990 and 2015 (Table 13.2 and Fig. 13.1). The variability
195 between them is tremendous: China built-up growth is two times higher than its
196 urban population progression and USA 4.2 times higher, but India, even it is the
197 third country in absolute terms for urban morphological expansion, it is much below
198 its urban demographic growth; 8.2% versus 19%. China alone concentrates about one
199 quarter of the world urban built up expansion. USA constitutes also a marker of the
200 variability with its 25,000 km² of added built-up associated to an extremely limited
201 demographic urban growth: 3.3% compared to 14.2% for the built-up imprint. Urban
202 Europe and Japan experiment also conversions of land use at a much higher rate than
203 their demographic stagnation would request.

Table 13.2 The 20th largest contributing countries to world's urban built-up expansion from 1990 to 2015

Rank	Country	Built-up		Urban population		Ratio B.U. Gro./Pop. growth
		Growth	Weight	Growth	Weight	
1	China	23.61	16.30	11.53	19.59	2.05
2	United States	14.23	17.69	3.35	3.80	4.25
3	India	8.24	5.17	22.28	19.33	0.37
4	Indonesia	4.60	3.44	3.73	3.75	1.23
5	Nigeria	3.44	1.89	4.23	2.56	0.81
6	Brazil	2.05	2.90	2.83	2.68	0.73
7	South Africa	1.88	1.61	0.94	0.68	2.01
8	Mexico	1.83	1.71	2.03	1.65	0.90
9	Japan	1.62	4.34	0.21	1.88	7.83
10	Italy	1.36	2.01	0.13	0.74	10.09
11	Germany	1.33	3.03	0.08	0.95	17.07
12	France	1.31	2.07	0.21	0.66	6.18
13	Russia	1.23	3.16	-0.37	1.85	
14	Turkey	1.16	1.01	1.23	1.04	0.94
15	RDC	1.15	0.60	1.83	0.92	0.63
16	Ghana	1.07	0.59	0.60	0.35	1.78
17	Vietnam	0.95	0.64	1.27	1.39	0.75
18	Malaysia	0.91	0.81	0.59	0.40	1.54
19	Pakistan	0.90	0.65	4.27	2.79	0.21
20	Thailand	0.90	0.78	0.56	0.77	1.60
	Sum	73.77	70.39	61.54	67.78	1.20
	World	100.00	100.00	100.00	100.00	

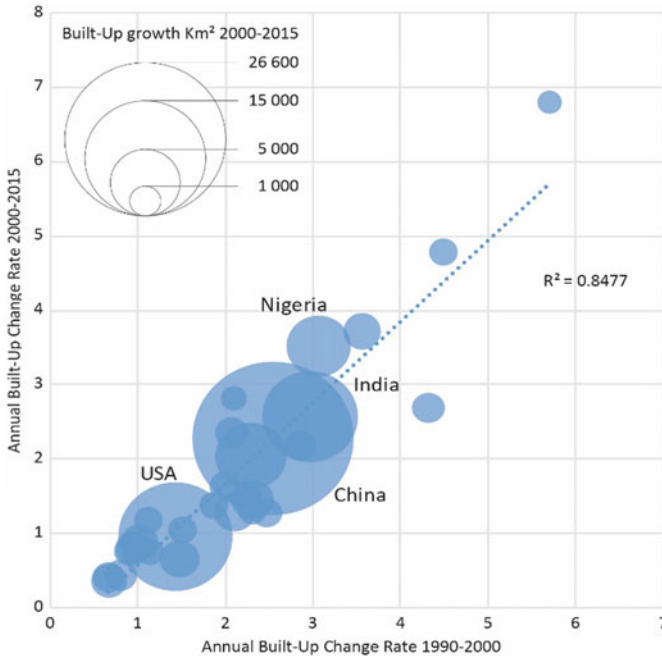


Fig. 13.1 Built-up annual growth rate during 1990–2000 and 2000–2015 for the 30 largest contributors to change (>80% of the total)

204 Regarding global regional differentiation, Asia experiments the fastest increase
 205 of its share of urban built-up followed by the African continent (Table 13.3). Never-
 206 theless, their share of built-up is not yet proportional to their high population weight.
 207 Density their remains necessarily higher, but it tends to decline. The share of all the
 208 other regions declines. Remarkably, the trajectory of North America and Europe are
 209 diverging. Europe urban built-up continues to expand more rapidly than its urban
 210 population growth while, in Northern America, this difference tends to reduce.

211 The urban sector captured with the Global Human Settlement methodology dis-
 212 tinguishes two complementary territorial configurations in reference to the 1 km²
 213 gridded approach: (i) densely populated areas or cities and their immediate periph-
 214 eries and (ii) intermediate density areas composed of towns and diffuse suburban
 215 milieus (Pesaresi et al. 2016b). The first category called Urban Centre regroups
 216 more than 13,000 morphological agglomerations defined as contiguous spatial units
 217 of the 1-km² grid cells (four-connectivity gap filling)⁷ with more than 50% of build-
 218 up and/or a minimum threshold of 1500 inhabitants per cell. Urban Centre should

⁷The goal for the high-density clusters is to identify urban centres without any gaps. Therefore, enclaves needed to be filled. If the central square is not part of a high-density cluster, it will be added to a high-density cluster if five or more of the eight surrounding cells belong to a single high-density cluster. This rule is applied iteratively until no more cells can be added.

Table 13.3 Regional repartition of urban built-up and population from 1990 to 2015

	Share urban built-up (%)			Share urban population (%)			Built-up/Pop. ratio		
	1990	2000	2015	1990	2000	2015	1990	2000	2015
World	100.0	100.0	100.0	100.0	100.0	100.0	1.00	1.00	1.00
Africa	8.31	9.28	10.90	10.9	12.4	15.5	0.76	0.75	0.70
Asia	35.16	36.89	39.74	64.0	64.1	62.8	0.55	0.58	0.63
Europe	25.35	23.29	20.81	12.2	10.5	8.7	2.07	2.22	2.38
Latin America and Car.	8.64	8.65	8.03	8.0	8.2	8.3	1.08	1.06	0.97
Northern America	20.66	20.14	18.93	4.4	4.4	4.2	4.66	4.63	4.47
Oceania	1.89	1.75	1.60	0.4	0.4	0.5	4.33	4.05	3.40

(Built-up/Pop ratio = built-up share divided by population share)

219 have a minimum of 50,000 inhabitants. The second category named Urban Cluster
 220 includes some 300,000 peri-urban territories and towns composed of contiguous
 221 one-km² grid cells having more than 300 inhabitants per square kilometre and a
 222 minimum of 5000 inhabitants by agglomerate unit (8 connectivity). Through this
 223 dichotomy of urban perimeters, we are able to better qualify what is belonging to
 224 the sprawl. It will occur in the lesser dense urban areas bellow 1500 inhabitants per
 225 kilometres. Nevertheless, using here only the country summary tables, we are not
 226 able to qualify precisely the amplitude of the sprawl, as some of the urban clusters
 227 are not contiguous peripheries of urban centres. Some of them constitute forms of
 228 diffuse or disperse urbanization rather than sprawl per say.

229 The density (inhabitants per square kilometre) is globally stagnating but this average
 230 is made of contrary trends (Table 13.4a, b). It declines continuously in Asia as
 231 well in Europe, in denser cores as well as in their peripheries. Other drivers than
 232 population accommodation are at stake in this trend. The deconcentrating trend concerns
 233 first-of-all the cities, their cores and immediate peripheries but it expands at
 234 a slower pace on the diffuse urban sector. Conversely, densification of high-density
 235 areas characterizes Africa, Oceania and Latin America. At a slower pace, the North

Table 13.4 a Inhabitants per square kilometre (1-km² grid—DEGURBA), **b** annual variation of density (inhabitants per square kilometre)

a						
	High density area			Low density area		
	1990	2000	2015	1990	2000	2015
World	5422	5338	5345	1676	1633	1551
Africa	5516	5547	6063	1988	1943	1852
Asia	7095	6792	6431	1974	1868	1695
Europe	3702	3615	3575	1169	1110	1056
Latin America	5404	5447	5823	1643	1637	1638
Northern America	1749	1763	1825	760	774	797
Oceania	1681	1843	2211	1130	1188	1329

b				
	High density area		Low density area	
	1990–2000	2000–2015	1990–2000	2000–2015
World	3	1	−4	1
Africa	3	34	−4	−6
Asia	−30	−24	−11	−12
Europe	−9	−3	−6	−4
Latin America and Car.	4	25	−1	0
Northern America	1	4	1	2
Oceania	16	25	6	9

Table 13.5 Square meters added per year and per inhabitant

	Urban area		High density area		Low density area	
	1990–2000	2000–2015	1990–2000	2000–2015	1990–2000	2000–2015
World	1.39	1.12	2.57	1.77	1.21	1.05
Africa	1.64	1.31	2.33	1.46	0.95	1.12
Asia	1.01	0.94	1.08	0.94	0.90	0.92
Europe	1.58	1.25	0.90	0.81	2.38	1.80
Latin America and Car.	1.48	0.71	1.66	0.82	1.15	0.48
Northern America	5.53	3.58	6.80	4.57	3.54	1.76
Oceania	3.15	2.14	4.79	2.64	0.80	1.33

Source Built-up GHSL; reference Population 2000 and 2015

236 America's paradigmatic sprawl seems to decelerate too and, eventually, agglomerates
237 re-densify there.

238 With the number of meters added per inhabitant and per year, we appreciate more
239 precisely how the expansion process slowed down vis-à-vis the population whatever
240 the urban sector, dense or less dense (Table 13.5). The trend is much contrasted from
241 region to region: the densification in Africa, Oceania and Latin America diverges
242 with de-densification in Asia and Europe, especially for the dense areas. Northern
243 America tends to stagnate. In this last region, the sprawl has not stopped but only
244 decelerated, and yet Northern America experiments the highest increase in square
245 meters added per inhabitant 3.6. Nevertheless, the subprime crisis reflects in the way
246 the annual built-up footprint growth is slowing down, compared to the respective
247 population growth (Table 13.6).

248 Convergence of built-up growth in densest and lesser-inhabited urban sectors
249 characterizes the global trend apprehended at the macro-region level (Table 13.6). A
250 gradual decrease of the physical expansion drives this conjunction of trends.

251 Everywhere, annual built-up rate of growth declines except in Africa low-density
252 areas. It has certainly to do with a deficiency in land governance and physical planning
253 leading to an extensive dynamic of sprawl by juxtaposition of individual houses.

Table 13.6 Annual growth rate of population and built-up for the two urban sectors (%)

	High density area				Low density area			
	Population		Built-up		Population		Built-up	
	1990–2000	2000–2015	1990–2000	2000–2015	1990–2000	2000–2015	1990–2000	2000–2015
World	2.30	1.81	1.86	1.47	1.23	0.88	1.40	1.18
Africa	3.80	3.50	3.32	2.44	2.32	2.12	2.00	2.45
Asia	2.44	1.79	2.22	1.87	1.29	0.75	2.05	1.85
Europe	0.44	0.10	0.56	0.49	-0.10	-0.08	1.01	0.68
Latin America & Car.	2.70	1.99	1.90	1.01	1.43	0.83	1.27	0.54
Northern America	2.46	2.00	1.80	1.26	0.48	0.47	0.85	0.42
Oceania	3.29	2.07	1.24	0.83	0.70	1.41	0.26	0.52

13.4 Beyond the Relationship Between Population Growth and the Built Environment: A Diverse World

If the decrease in population growth goes together with the decelerating of built-up densification⁸ and expansion, the relation is far from being uniform. In fact, for the entire urban footprint of the 156 countries with significant figures, the correlation coefficient (Pearson) between the annual population change and the annual built-up growth for the 2000–2015 is solid, established at 0.507. It is sensibly higher than the previous period of observation (1990–2000) when it was at 0.470. Population dynamics still matter in the way cities are expanding nevertheless the correlation between density and built-up growth tends to decline (0.367–0.224).

In the dense urban sector also, globally, the independence of trajectories tends to increase during the last period of observation ($R = 0.683$ against $R = 0.528$ for the previous decade). It is high and stable in less dense areas ($R = 0.560$ and 0.552).

The relation varies from region to region and tends also to consolidate or stays stable. For instance, in Africa for the last period the correlation is 0.421 (0.310 previously). In Latin and Central America, it declines very little from 0.410 to 0.384. Asia, excluding the Middle East countries, exposes a strong and increasing relation passing from 0.734 to 0.797. In Europe, it goes up very significantly to reach 0.832, from 0.568 previously. In this last, slow population change, even decline sometime, goes hand-to-hand with a limited built-up expansion.

The heterogeneity of the relation (only $\frac{1}{4}$ of the variance of one growth variable can be statistically explained by the other) can be appreciated when mapping residuals of the linear relation between built-up and population growth for the last fifteen years observed (2000–2015). The map opposes a major part of Africa and Asia to Europe and America including Latin America (Fig. 13.3).

This is not a simple economic and wealth dichotomy nor a demographic regime that drive the contrast we observe on the residuals mapping at the world scale (Figs. 13.2 and 13.3). The relationship is not linear ($R^2 = 0.25$), nor even polynomial ($R^2 = 0.27$) but appears as almost random (Fig. 13.2) reflecting a complex, various, contextual and multifactorial explanation of built-up expansion. The maximum contrast opposes, in one hand, countries with high population growth articulated to an extremely great built-up increase to, in the other hand, countries where urban land conversion and construction is very limited and sometime extreme population growth but more often a sluggish population growth. Globally it reflects a dichotomy between countries characterized by a rapid urban transition combining physical expansion and demographic growth and nations with a limited urban development.

An accelerated urban sprawl affects East Africa from Ethiopia (4.7% per year compared to 2.7 for urban population) to Malawi including Burundi and Rwanda (5.9% vs. 2.7). South Sudan appears here too as a post war speculative (re)construction

⁸By densification, we understand here more continuous urbanization measured at 38 m. The approach did not provide direct information about vertical densification and the transition from detached houses landscape to apartments. Nevertheless, increases of density are indicators of more people in some areas more often linked to building having more floors and apartments.

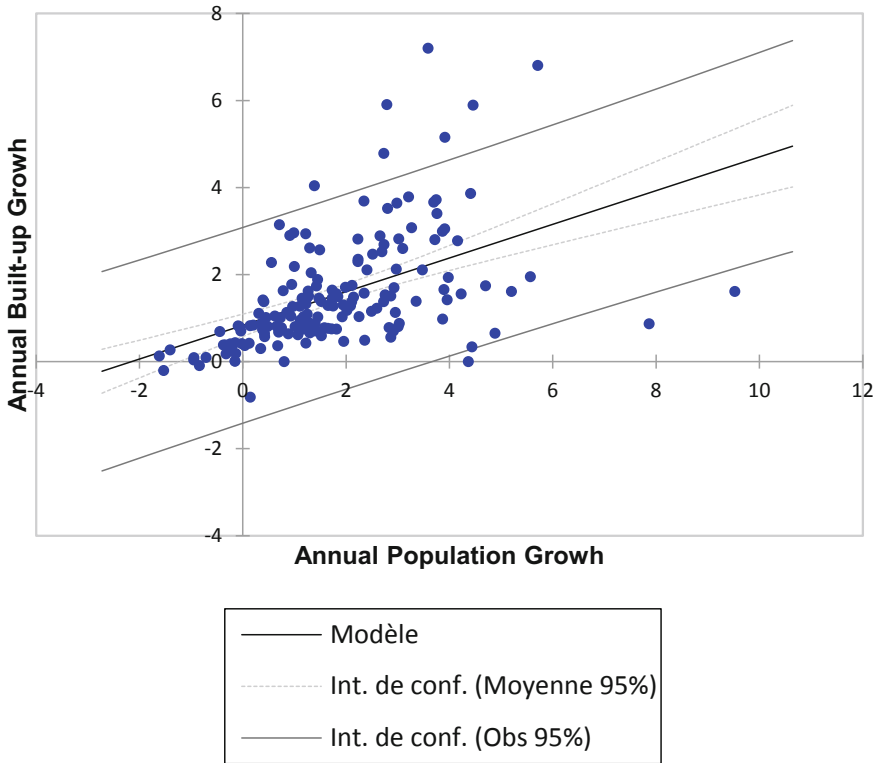


Fig. 13.2 Regression of annual built-up growth 2000 to 2015 by annual population growth ($R = 0.507$; $R^2 = 0.257$)

293 and quest to fix capital (5.8 vs. 4.4). There, surplus pour massively into plots and
 294 construction at a rhythm much higher than their population growth demand. West-
 295 ern Africa, notably Burkina Faso (3.7%/y for built-up) and Nigeria (3.5%) are other
 296 significant cases of rapid urban landscape metamorphosis, less extreme but yet very
 297 high. They are characteristic of a public governance of land that induces a selective
 298 redistribution of the public domain toward civil servants, army officers and supporters
 299 as a path to preserve the stability of the regime.

300 Houses, apartments and plots constitute as many tangible and irremovable assets,
 301 which protect their owners in the context of high inflation and against the poor return
 302 and lack of security of financial wealth. In those configurations, we found a majority
 303 of lower-income countries with a limited banking system poorly inclusive.

304 In such situation, we found also most of the Asian countries. Cambodia,
 305 Bangladesh and Myanmar represent extreme cases. The sustained pace of 2.2% per
 306 year of China physical expansion of cities is of particular significance as it represents
 307 almost of quarter of all the physical urban expansion of the world between 2000 and
 308 2015. There, despite a lacklustre demographic growth limited to 0.5%, the built-up

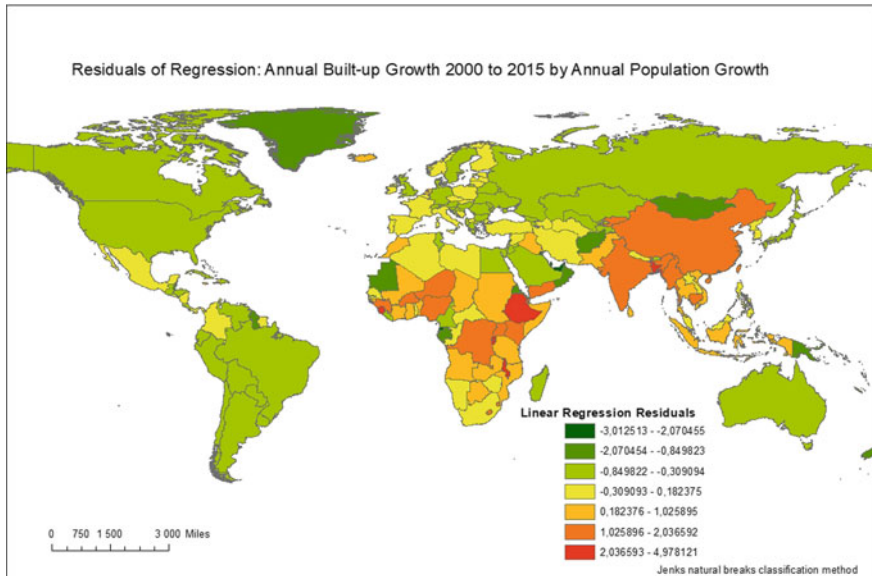


Fig. 13.3 Regression residuals: annual built-up growth by annual population growth (2000–2015)

309 footprint continues to expand fast at 3.8% per year since 2000. In 15 years, almost
310 14 m have been added per urban 2015 inhabitant.

311 This trend exemplifies a group of countries that a Chinese colleague Hsing (2010)
312 called “land-driven development machine”. A variant would be the “property state”
313 as coined by Haila (2016) looking at Singapore public management of urban land
314 rent. There, the commodification of land supports the economic growth. It backs
315 money creation and credit development. It is important to understand at the global
316 scale this process has a complex decision game not simply driven by market forces but
317 mediated by state policies *vis-à-vis* land supply and rate of credit as well by various
318 “cultural ethics” determining the conception of home ownership for household and
319 institutional in their management of assets and embeddedness. Consequently, it leads
320 to an extreme consumption of space. Hence, housing oversupply characterizes today
321 Chinese urban landscape. In 2014, the China Household finance Survey underlined
322 that 40% of the annual housing supply would be enough to meet the additional
323 housing demand. This year (2018), the vacation rate has reached 22%, it was already
324 of 20% in 2011 (Li 2018). This represents some 50 million units!

325 India is not far, with an urban built-up growth at 2.6% per year but associated
326 to a much higher demographic growth (1.6 per year). Beside this consequent land
327 conversion to urban uses, due to market distortions and severe inequalities,⁹ the
328 improvement of the urban housing condition remains very limited. Some 65 million

⁹Oxfam reports that in 2017, the richest 1% in India cornered 73% of the wealth generated. Official figures about urban inhabitants living below poverty line is 25.7% (Rangarajan Committee 2011). It represents today more than 100 million persons.

329 urban Indians or 17% of the urban citizen lives in slums and their number continue
 330 to increase. The real estate boom, which constitutes the major component of the new
 331 urban frontiers, generates an offer targeting the upper-middle class and the riches
 332 who are looking in real investment to fix cash.

333 It is particularly important to detail the Chinese and Indian cases because between
 334 them, they account for nearly a third of the global urban built-up expansion from
 335 2000 to 2015.

336 Major post-industrial democracies could have also experimented faster built-up
 337 footprint spread vis-à-vis their population growth. USA is part of this trend with
 338 a built-up expanding at 0.95% per year when the urban population continues to
 339 growth at 1.11%. Nevertheless, because urban USA is paradigmatic of the extensive
 340 urban with its suburbs and yet represents the second share of the world built-up
 341 growth (14%), its trend is of a particular importance. Without the subprime crisis,
 342 it could have been even bigger. To some extent, it is comparable to several major
 343 Latin American countries and Canada as well: Brazil stands at 1.33 versus 1.03 and
 344 Argentina at 0.61 versus 1.07.

345 Europe is representing an average relation between urban built-up expansion and
 346 population growth: only could we distinguish a set Western and Southern Europe
 347 vis-à-vis Northern and Eastern Europe. The second exposes a slower built-up rate of
 348 change in view of their demographic growth. It is undoubtedly necessary to link this
 349 time lag to a process of catching up between the countries of the South and Northern
 350 Europe, but also to less control over land use—in other words, to regulations that are
 351 more flexible.

352 The most deficit-oriented countries in term of built-up growth vis-à-vis their popu-
 353 lation change are, for a part, rich petroleum monarchies (UAE, Qatar, Kuwait and
 354 Oman) with an extremely high demographic rate of growth (between 5 and 7% per
 355 year) and a built-up growth below one percent per year.¹⁰ In the same group are coun-
 356 tries often poor or/and affected by conflict such as Afghanistan where demographic
 357 growth remains strong.

358 **13.5 Economic Drivers of Land Conversion and Urban** 359 **Built-Up Growth**

360 If, globally, the recent urban physical expansion (2000–2015) did not respond linearly
 361 to the variability of demographic growth from country to country, the link to the
 362 distribution of income by country points to a dissimilarity in trend. There is not
 363 much difference between high-income (HIC) and low-income countries¹¹ (LIC):
 364 0.475 versus 0.501, except that the relation is decreasing in HIC (0.596 previously)

¹⁰Here we could face a form of underestimation of the built-up change and of densification by verticalisation.

¹¹We use the UN income group classification: https://esa.un.org/unpd/wup/cd-rom/WUP2014_DOCUMENTATION/WUP2014_DEFINITION_OF_MAJOR_AREAS_AND_REGIONS.pdf.

365 and increasing in LIC (0.370). The tendency to a lower correlation of the urban
366 built-up expansion and the population demand/pressure goes with an accomplished
367 demographic transition, the stabilisation of rural to urban migration and an increase
368 of wealth generated.

369 The population, its growth, did not explain totally and uniformly the intensity of
370 the built-up imprint expansion. Nevertheless, it constitutes the best proxy expressing
371 the demand for housing, productive activities and infrastructures. The artificialisation
372 of soil and new constructions within and around cities answers to multiple goals that
373 the demographic growth is not covering fully: (i) Buildings constitute also places
374 for multiple economic functions which are not strictly proportional to population
375 and (ii) housing is answering to very different segments of demand depending of
376 wide spectrum of inequalities. Furthermore, edifices incorporate a financial value
377 detached of their use value. Fixation of richness in plots and built assets tends to
378 generate a dynamic of construction more and more de-correlated of the population
379 demand. It certainly reflects in the degree of financialisation of economies, wealth
380 formation and inequalities.

381 Before going further in the macro-economic analysis, we should notice that the
382 family size weight and change by country considered as a proxy of the level of
383 nuclearisation that should affect the housing demand is not correlated to built-up
384 weight nor its change (Table 13.7). Correlations are also non-existent with proxies
385 related to construction, whether it is the share in world concrete production or the
386 weight of fixed capital in GDPs. The weight of the real estate and financial sector
387 in the GDP could perhaps give a better result, but it is not easy to gathers for all the
388 countries of the world a proper harmonized and updated indicator.

389 Significant correlation between economic and urban built-up indicators opposes
390 urbanized land “stock” world distribution by country and its evolution to growth
391 rate of change and densities of urban built-up by country. It means that, when the
392 GDP per capita is negatively correlated with the annual growth rate of the built-up
393 ($R = -0.317$) as well to the average urban density per country, it is positively cor-
394 related with the distribution of the world built-up by country ($R = 0.456$); in other
395 words, with the largest and richest nations. A reverse dichotomy characterizes the
396 link between annual GDP growth by country from 2000 to 2015 and built-up share
397 ($R = -0.343$) versus annual growth rate of built-up ($R = 0.336$) and density
398 ($R = 0.420$). Here we have a first indication of how the growth of housing by country
399 is localized, in an inversely proportional way, to the various national economic
400 weight; built-up growth responds in priority to a demand linked to strong demo-
401 graphic pressure, hence the link with densities also. It should be noticed here that
402 the relationship is not very simple since the weight of countries in the world GDP
403 in 2015 is very weakly correlated to their share in the global urban built-up growth
404 ($R = 0.180$), nor to the share of wealth ($R = 0.128$), but their growths are correlated.

405 If there is no link with inequality indicators such as the repartition of millionaires
406 or Gini indices, there are significant correlations with the distribution of wealth in
407 general and by quantile. The relationship is more significant than with the global
408 distribution of the GDP. Wealth reflects more the material capital encapsulated in
409 the built-up footprint. The distribution of global urbanized territories by country is

Table 13.7 Correlation (Pearson) between urban change indicators and economic proxies

Variables	Annual growth rate urban population 2000–2015	Annual growth rate urban built-up 2000–2015	Urban density 2015	Urban density change 2000–2015	Urban built-up share 2015	Variation urban built-up share 2000–2015
^a Family size—2015	-0.033	-0.059	-0.025	0.062	0.082	0.088
^a Family size change 2000–2015	-0.076	0.013	-0.094	-0.160	0.012	0.006
^b Share of World GDP—2015	-0.143	-0.095	-0.137	-0.064	0.180	0.098
^b Annual growth rate GDP 2000–2015	0.359	0.336	0.420	0.101	-0.343	-0.231
^b GDP Per Capita—2015	-0.098	-0.317	-0.301	0.146	0.456	0.298
^b Annual growth rate per capita GDP 2000–2015	-0.281	0.029	0.068	-0.273	-0.189	-0.150
^c 2015 share immobilized capital in GDP	0.127	0.100	0.213	-0.047	-0.194	-0.166
^d Variation cement prod.—2000–2012	-0.085	-0.018	-0.113	0.062	0.020	-0.016
^d Share World cement prod.—2012	0.030	-0.012	0.037	0.027	-0.034	-0.034
^a Share World millionaire per country	-0.096	-0.090	-0.153	-0.028	0.149	0.070
^a Wealth to GDP per adult—2015	-0.265	-0.325	-0.235	-0.021	0.399	0.246
^a Share of adult under 10,000 wealth—2015 (USD)	0.111	0.402	0.228	-0.151	-0.383	-0.213
^a Share 10,000–100,000—2015	-0.234	-0.443	-0.222	0.176	0.254	0.122
^a Share 100,000–1 million—2015	-0.079	-0.247	-0.256	0.119	0.537	0.373
^a Share over 1 million—2015	-0.083	-0.190	-0.271	0.046	0.367	0.219
^a Gini per country—2015	0.006	0.127	-0.017	0.018	-0.038	0.025
^a By country share of total wealth 2015	-0.107	-0.081	-0.148	-0.044	0.131	0.060
^a Share change world total wealth 2010–2015	0.035	0.037	-0.049	0.002	-0.195	-0.128
^a Wealth per adult—2015	-0.102	-0.236	-0.274	0.077	0.458	0.297
^a Financial wealth per adult—2015	-0.084	-0.212	-0.284	0.075	0.478	0.354

(continued)

Table 13.7 (continued)

Variables	Annual growth rate urban population 2000–2015	Annual growth rate urban built-up 2000–2015	Urban density 2015	Urban density change 2000–2015	Urban built-up share 2015	Variation urban built-up share 2000–2015
^a Non-financial wealth per adult—2015	−0.098	−0.231	−0.259	0.087	0.320	0.188
^a Debt per adult 2015	−0.071	−0.189	−0.243	0.092	0.403	0.315
^a Var share of nonfinancial wealth 2010–15	0.089	−0.002	0.099	0.118	−0.067	−0.060
^a Debt to wealth in 2015	−0.128	−0.254	−0.186	0.137	0.211	0.175

The values in bold are different from 0 to a level of meaning $\alpha = 0.05$; *Sources* ^aWealth data Credit Suisse Wealth Report 2016; ^bThe World Bank, ^cOCDE, ^dU.S. Geological Survey, ^eGlobal Data Lab

410 strongly linked to the weight of the high income and capital in national economies:
411 the weight of the upper middle classes (100,000 to 1 million wealth) and the richest
412 (over 1 million) ($R = 0.537$).

413 Conversely, the rate of change of built-up imprint is correlated with the weight
414 of the most modest adult populations, below 10,000 USD ($R = 0.402$). It exposes
415 the materiality of a meta-trend of convergence. The least developed countries are
416 experiencing an urban sprawl that corresponds to an expansion of popular housing
417 and thus to an overall improvement in housing conditions. Multi-storey apartment
418 buildings remain often extremely limited accenting the sprawl during the first cycle
419 of land conversion.

420 The analysis of the same set of correlations between building growth and economic
421 indicators by countries gathered by income groups confirms the contrast between
422 countries whose building expansion is insufficient vis-à-vis the demographic pressure
423 they experiment and advanced and rich countries where building expansion is more
424 and more uncorrelated to the immediate final user demand (inhabitants). In this last,
425 the demand is mediated by complex market rationalities. Land transformation and
426 real estate fuel, both, the physical production of cities and the enlargement of the
427 financial sector.

428 Lower-income countries (LIC) expose a significant link between the share of debt
429 vis-à-vis the wealth and the built-up growth rate: $R = 0.465$ versus $R = 0.105$ for
430 high-income countries (HIC), but the debt share per adult link to built-up growth is
431 more a characteristic of HIC ($R = 0.308$). It contrasts the limited capital of LIC with
432 HIC. In HIC, credit could expand individual wealth including built capital. In other
433 words, the built-up growth in HIC is more dependent of the debt level.

434 In lower-income countries, the density in 2015 is inversely correlated to the degree
435 of inequalities ($R = -0.434$) and positively to the weight in the world built-up (R
436 $= 0.449$). Dedensification, notably in larger LIC countries, could have a link with
437 increasing inequalities. The strong correlation between density and the share of adult
438 below 10,000 USD in LIC confirms it ($R = 0.526$). There, physical expansion has to

439 do with the capture of the urban rent by the upper class. In LIC the growth of GDP
 440 per capita is significantly correlated to built-up growth ($R = 0.420$) while it is the
 441 opposite for HIC ($R = -0.329$).

442 We know after Piketty (Alvaredo et al. 2017) in particular for LIC and medium
 443 low-income countries including BRICS that the increase of GDP per capita goes
 444 with strong upsurge in inequalities. The capture of wealth including urban land and
 445 their rent by a very limited and rich minority is at stake. There, wealth grows at the
 446 rate of return to capital, a rate that normally exceeds the economic growth rate. The
 447 expansion of built-up environment encompasses the current tendency of fast growing
 448 economies to have ever-increasing ratios of wealth to income. The shaping of new
 449 peripheries involves a permanent reconversion of capital from financial (monetary)
 450 to nonfinancial (commodity) assets, and back again. Here we confirm the intuition
 451 of a growing disconnection between the production of new urban spaces and the
 452 final demand of users, inhabitants, productive activities, services and infrastructures.
 453 Nevertheless, in general ($R = 0.498$) it is indeed where the population growth more
 454 rapidly that the built-up is expanding faster but it is not meeting straightforward this
 455 rising demand.

456 The multifactorial unsupervised clustering provides a typology of urban growth
 457 articulated to the distribution of wealth (Fig. 13.4). Its mapping clearly contrasts
 458 advanced and rich economies in majority slowing down in term of population growth
 459 as well built-up footprint change (type 3) and developing and poor nations where
 460 urban population and built-up rate of growth are the highest (type 5). It consists

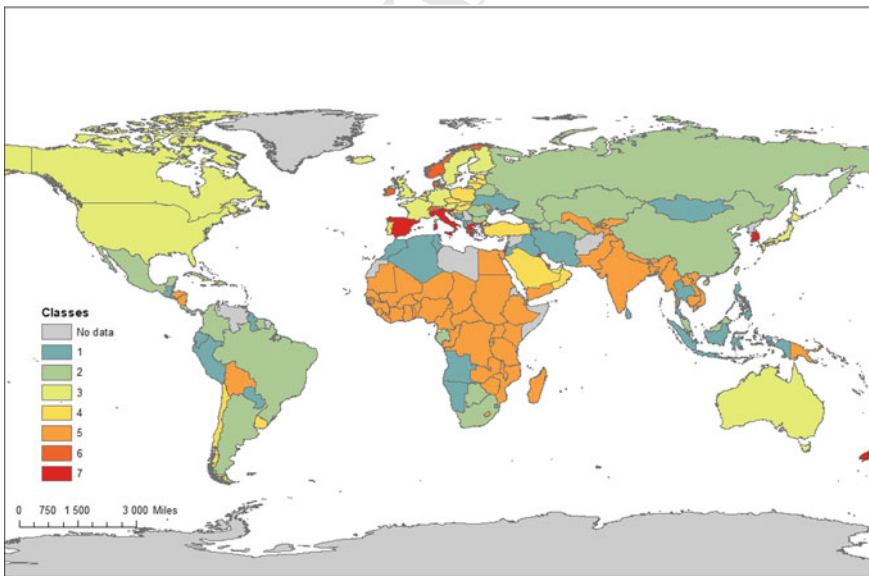


Fig. 13.4 City growth and economic factors: k-means unsupervised clustering

461 mainly of sub-Saharan and South-Asian countries that are experimenting the fastest
462 expansion of their urban footprint (Table 13.8).

AQ3

463 The other classes represent various intensity of built-up growth articulated to
464 GDP per capita and wealth's quartile distribution. The class 1, for instance, gathers
465 transitional countries relatively poor but with a significant middle class and medium-
466 rich. There, the urban population pressure is less intense than in poorest countries
467 (class 5) but built growth is high as well the GDP growth. The class two is more
468 gathering BRICS type of countries.

469 The typology suggested by this K-Means clustering confirms a trend towards
470 convergence through the catching-up effect of the poorest countries and a slowdown
471 in built-up growth in the richest countries, due to the densification and structural
472 slowdown in economic growth. In the poorest countries, the high intensity of urban
473 built-up expansion reflects both continuing high population pressure and a structural
474 trend towards housing improvement. Built-up intensity of construction is often all
475 the stronger because buildings constitute a safe haven for fixing their economies or
476 accessing mortgage credit. In these often fast-growing economies, the construction
477 and ownership of buildings is also the driving force behind growing inequality.

478 **13.6 Conclusion: The Urban Built-Up Expansion Tends** 479 **to Diverge from Population Growth**

480 This first exploration of the dynamics of building expansion by country using a
481 harmonised geodatabase for the entire world reveals very contrasting trends. It is
482 clear that population growth in cities remains the most important factor determining
483 urban built-up spread, but countries differ. In particular, China, where urban built-up
484 expansion continues at a sustained pace despite the significant decline in population
485 growth. The extent of built-up growth in and around Chinese cities accounted for a
486 quarter of the world's urban built-up increase between 2000 and 2015.

487 Americans are the world's second largest contributors to the global urban built-
488 up expansion. It remains disproportionate to the low population growth within
489 urban areas. However, the pace has slowed. The trend would even be towards a
490 re-densification of urban areas and in any case a decline in construction, which must
491 be linked to the 2008 subprime crisis.

492 Here we understand that the built-up growth is not simply a reflection of the
493 final demand for housing and therefore of demographic pressure or even driven
494 by the nuclearisation of families. Building is a material good whose value is also
495 interdependent with economic growth. The universal relationship between size and
496 density specific to laws of scale is certainly verified once again in the case of cities.
497 However, economic density or concentration of wealth tends to take precedence
498 over population mass to explain urban built-up expansion. As such, soil conversion
499 is increasingly associated with economic trends and wealth distribution. We show
500 here that there is a significant correlation between urban built-up expansion and

Table 13.8 Detailed legend of map 2 classes with value of variables for each class barycentre and weight of classes

Classes	Density	Population	Built-up	GDP Constant	GDP Per Capita 2015	Under 10,000 USD/Y	10,000–100,000	100,000–1 million	Over 1 million	Weight	Intra-class variance
	2015	Annual growth rate 2000–2015	2000–2015	2015 (wealth)	2015 (wealth)	2015 (wealth)	2015 (wealth)	2015 (wealth)	2015 (wealth)	2015 (wealth)	2015 (wealth)
1	2538	1.26	1.13	4.16	4334	65.2	17.7	9.7	0.9	31	2,024,606
2	2499	1.09	0.95	4.79	8481	66.4	18.7	5.8	0.4	23	3,842,214
3	2003	1.27	0.84	1.82	47,445	61.1	29.4	9.1	0.4	14	24,864,587
4	2263	0.88	0.72	3.54	16,758	67.7	16.5	8.2	1.4	16	10,160,750
5	3303	2.66	2.56	4.97	1188	68.1	19.9	7.9	0.5	56	1,967,539
6	2037	2.90	1.20	3.91	72,370	75.7	3.9	0.3	0.0	5	133,594,953
7	2560	1.31	0.80	2.14	29,999	59.9	26.4	12.9	0.8	8	31,444,633

Intra-class variance: 3.16%; Inter-classes: 96.84%

501 the weight of the upper middle classes, particularly in South Asia. In intermediate
 502 economies, increasing inequalities boosts extremely intense activity of construction.
 503 The capture of the global manufacturing activities and many IT services by these
 504 countries stimulates also there a gigantic dynamic of plant construction.

505 This first study remains at the global level of countries and compares them with
 506 each other. Further study is needed to examine the extent to which the intensity of
 507 urban expansion is correlated with the size of cities. Are the largest metropolitan
 508 areas expanding faster? Does the size and shape of city systems influence how and
 509 where land is converted to urban use? What is the precise share of the sprawl in the
 510 built-up growth?

511 This should lead us to question how to infer populations with measured built-up
 512 physical extension and thus how to generalize urban areas as DEGURBA does—
 513 today the DEGURBA urban population is overestimated. Other groupings are possible
 514 and likely to bring out more small towns at the expense of the extension of
 515 large urban areas as well as the extent of rural areas. In the immediate future, the
 516 approach tends to underestimate the emergence from below and thus the weight
 517 of rural localities that become small towns (see Russo et al. 2017). Nevertheless,
 518 the overall measurement of urban changes remains valid and robust, especially the
 519 harmonized built-up detection. The analyses and interpretations that we are receiving
 520 undoubtedly open up new avenues for qualifying and understanding, and even
 521 predicting, the spread of cities.

522 References

- 523 Alvarado, F., Chancel, L., Piketty, T., Saez, E., Zucman, G.: Global inequality dynamics: new
 524 findings from WID.world. *Am. Econ. Rev.* **107**(5), 404–409 (2017)
- 525 Angel, S., Blei, D.M., Civco, P., Lamson-Hall, J., Parent, N., Galarza Sanchez, K.: Atlas of Urban
 526 Expansion—The 2015 Edition. Edited by New York: The NYU Urbanization Project. Cambridge
 527 MA: The Lincoln Institute of Land Policy. U.N. Habitat, Nairobi, Kenya (2015)
- 528 Dijkstra, L., Poelman, H.: A harmonised definition of cities and rural areas: the new degree of
 529 urbanisation. Regional Working Paper 2014 WP 01/2014. Bruxelles: European Commission.
 530 Regional and Urban Policy (2014)
- 531 Dijkstra, L., Florczyk, A., Freire, S., Kemper, T., Pesaresi, M.: Applying the degree of urbanization
 532 to the globe: a new harmonized definition reveals a different picture of global urbanization. Paper
 533 prepared for the 16th Conference of IAOSOED Headquarter, Paris, France, 19–21 Sept 2018
- 534 Esch, T., Heldens, W., Hirner, A., Keil, M., Marconcini, M., Roth, A., Zeidler, J., Dech, S., Strano,
 535 E.: Breaking new ground in mapping human settlements from space—the Global Urban Footprint.
 536 *ISPRS J. Photogram. Remote Sens.* **134**, 30–42 (2017)
- 537 Florczyk, A.J., Airaghi, D., Ehrlich, D., Corban, C., Freire, S., Kemper, T., Maffeni, L., Melchiorri,
 538 M., Politis, P., Pesaresi, M., Sabo, F., Schiavina, M., Tommasi, P., Zanchetta, L.: Community pre-
 539 Release of GHS Data Package (GHS CR2018) in support to the GEO Human Planet Initiative.
 540 JRC Technical Report. Luxembourg: Publications Office of the European Union, 20 p. (2018)
- 541 Henderson, V.: The urbanization process and economic growth: the so-what question. *J. Econ.*
 542 *Growth* **8**(1), 47–71 (2003)
- 543 Hsing, Y.T.: The Great urban transformation: politics of land and property in China (2010)
- 544 Jun, C., Ban, Y., Li, S.: China: open access to Earth land-cover map. *Nature* **514**(7523), 434 (2014)

- 545 Leyk, S., Uhl, J.H., Balk, D., Jones, B.: Assessing the accuracy of multi-temporal built-up land
546 layers across rural-urban trajectories in the United States. *Remote Sens. Environ.* **204**, 898–917
547 (2018)
- 548 Li, X., Zhou, Y.: Urban mapping using DMSP/OLS stable night-time light: a review. *Int. J. Remote*
549 *Sens.* **38**(21), 6030–6046 (2017)
- 550 Lu, L., Guo, H., Pesaresi, M., Ehrlich, D., Ferri, S.: 11 assessment of fine-scale built-up area mapping
551 in China. In: *Global Urban Monitoring and Assessment through Earth Observation*, p. 217. CRC
552 Press (2014)
- 553 Melchiorri, M., Florczyk, A.J., Freire, S., Schiavina, M., Pesaresi, M., Kemper, T.: Unveiling
554 25 years of planetary urbanization with remote sensing: perspectives from the global human
555 settlement layer. *Remote Sens.* **10**(5), 768 (2018)
- 556 Pesaresi, M., Huadong, G., Blaes, X., Ehrlich, D., Ferri, S., Gueguen, L., Halkia, M., et al.: A
557 global human settlement layer from optical HR/VHR RS data: concept and first results. *IEEE J.*
558 *Sel. Top. Appl. Earth Obs. Remote Sens.* **6**(5), 2102–2131 (2013). [https://doi.org/10.1109/jstars.](https://doi.org/10.1109/jstars.2013.2271445)
559 [2013.2271445](https://doi.org/10.1109/jstars.2013.2271445)
- 560 Pesaresi, M., Ehrlich, D., Ferri, S., Florczyk, A., Freire, S., Halkia, M., Julea, A., Kemper, T.,
561 Soille, P., Syrris, V.: Operating procedure for the production of the Global Human Settlement
562 Layer from Landsat data of the epochs 1975, 1990, 2000 and 2014. Publications Office of the
563 European Union (2016a)
- 564 Pesaresi, M., Melchiorri, M., Alice, S., Kemper, T. (eds.): *Atlas of the Human Planet 2016: Mapping*
565 *Human Presence on Earth with the Global Human Settlement Layer*. Science for Policy report by
566 the Joint Research Centre (JRC). The European Commission's science and knowledge service
567 (2016b)
- 568 Russo, A.P., Serrano Giné, D., Pérez Albert, M.Y., Brandajs, F.: Identifying and classifying small
569 and medium sized towns in Europe. *Tijd. economische en sociale geografie* **108**(4), 380–402
570 (2017)
- 571 Seto, K.C., Fragkias, M., Güneralp, B., Reilly, M.K.: A meta-analysis of global urban land
572 expansion. *PLoS ONE* **6**(8), e23777 (2011)
- 573 Smith, D.A.: Visualising world population density as an interactive multi-scale map using the global
574 human settlement population layer. *J. Maps* **13**(1), 117–123 (2017)
- 575 Tikoudis, I., Oueslati, W., Dimitropoulos, A., Engelfriet, L.: *Rethinking Urban Sprawl: Moving*
576 *Towards Sustainable Cities*. OECD Publishing, Paris (2018)

Author Queries

Chapter 13

Query Refs.	Details Required	Author's response
AQ1	Kindly note that, Reference citation 'Dijkstra et al. (2014)' has been changed to 'Dijkstra and Poelman (2014)' so that this citation matches the list.	
AQ2	References 'Chun et al. (2014), Li (2018), Rangarajan Committee (2011)' are cited in the text but not provided in the reference list. Please provide the respective references in the list or delete these citations.	
AQ3	Please check and confirm if the inserted citation of 'Table 13.8' is correct. If not, please suggest an alternate citation.	
AQ4	References 'Jun et al. (2014), Pesaresi et sl. (2016a)' are given in the list but not cited in the text. Please cite them in text or delete them from the list.	

MARKED PROOF

Please correct and return this set

Please use the proof correction marks shown below for all alterations and corrections. If you wish to return your proof by fax you should ensure that all amendments are written clearly in dark ink and are made well within the page margins.

<i>Instruction to printer</i>	<i>Textual mark</i>	<i>Marginal mark</i>
Leave unchanged	... under matter to remain	Ⓟ
Insert in text the matter indicated in the margin	∧	New matter followed by ∧ or ∧ [Ⓢ]
Delete	/ through single character, rule or underline or ┌───┐ through all characters to be deleted	Ⓞ or Ⓞ [Ⓢ]
Substitute character or substitute part of one or more word(s)	/ through letter or ┌───┐ through characters	new character / or new characters /
Change to italics	— under matter to be changed	↙
Change to capitals	≡ under matter to be changed	≡
Change to small capitals	≡ under matter to be changed	≡
Change to bold type	~ under matter to be changed	~
Change to bold italic	≈ under matter to be changed	≈
Change to lower case	Encircle matter to be changed	≡
Change italic to upright type	(As above)	⊕
Change bold to non-bold type	(As above)	⊖
Insert 'superior' character	/ through character or ∧ where required	Υ or Υ under character e.g. Υ or Υ
Insert 'inferior' character	(As above)	∧ over character e.g. ∧
Insert full stop	(As above)	⊙
Insert comma	(As above)	,
Insert single quotation marks	(As above)	Ƴ or ƴ and/or ƶ or Ʒ
Insert double quotation marks	(As above)	ƶ or Ʒ and/or Ʒ or ƶ
Insert hyphen	(As above)	⊥
Start new paragraph	┌	┌
No new paragraph	┐	┐
Transpose	└┐	└┐
Close up	linking ○ characters	Ⓞ
Insert or substitute space between characters or words	/ through character or ∧ where required	Υ
Reduce space between characters or words		↑