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The New Geography of Contemporary Urbanization and the Environment

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Key Words

agglomeration, climate change, drivers of urbanization, urban form and function, governance and institutions, sustainability

Abstract

Contemporary urbanization differs from historical patterns of urban growth in terms of scale, rate, location, form, and function. This review discusses the characteristics of contemporary urbanization and the roles of urban planning, governance, agglomeration, and globalization forces in driving and shaping the relationship between urbanization and the environment. We highlight recent research on urbanization and global change in the context of sustainability as well as opportunities for bundling urban development efforts, climate mitigation, and adaptation strategies to create synergies to transition to sustainability. We conclude with an analysis of global greenhouse gas emissions under different scenarios of future urbanization growth and discuss their implications.

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Urbanization: contemporary urbanization includes changes in demographics, land cover, and economic processes and characteristics of a geographic area

Urban area: a geographical area containing high population and large-scale infrastructure density; encompasses concepts of town, city, metropolitan area, megacity, megalopolis, and conurbation

1. INTRODUCTION

The geography of urbanization is rapidly changing and in multiple dimensions. These changes in the characteristics of contemporary urbanization are fundamentally transforming the relationship between cities and the global environment. We have now entered the Century of the City, and urbanization will be a defining social, economic, and environmental characteristic of the new centennial. While scientists agree that we are presently living in the era of the Anthropocene, the period in Earth's history when humans are altering the functioning of the global environment, we propose the term Astycene as a more accurate description of the new urban era where "anthropos" is an "astos," a dweller of an urban area.[1] The Century of the City presents both global environmental challenges and opportunities.

Urbanization creates the most human-dominated landscapes and drives local and regional environmental changes by transforming land cover, hydrological systems, and biogeochemistry (1). Worldwide, urban expansion is one of the primary drivers of habitat loss and alteration and of plant and animal species extinction (2, 3). Yet, the concentration of people, resources, and economic activity also presents opportunities for transitions to sustainability. High population densities and compact urban design are required to support walkable neighborhoods and mass transit alternatives to the automobile. Compact urban development coupled with high residential and employment densities can reduce energy consumption, vehicle miles traveled, and carbon dioxide (CO_2) emissions (4). Concentrated populations can also save land for agriculture, wildlife, and habitat by using less land for urban development. The trade-offs between environmental challenges and opportunities will depend in large part on how and where urban areas expand, urban lifestyles, and consumption patterns as well as the ability of institutions and governance structures to address adequately these challenges.

Over the past two decades, there has been an increase in the number of studies concerning the interactions between urbanization and global environmental change. There is a growing community of researchers that studies the effects of urbanization on the global environment and the impacts of global change on urban areas. These bidirectional interactions between urbanization and global change are a core component of the Urbanization and Global Environmental Change project of the International Human Dimensions Program on Global Environmental Change (5).

The environmental literature of the 1960s through the 1980s predominantly viewed

[1]The term is derived from the Greek words $\alpha\sigma\tau\upsilon$ (asty, city, town) and $\kappa\alpha\iota\nu\acute{o}\varsigma$ (cene, new).

urbanization and cities as environmental ills, but recent research is revealing a more complex relationship between urbanization and the environment. Some suggest that urbanization—through the associated economic development and rises in income—will increase environmental awareness, protection, and quality; others point to problems with this hypothesis by focusing on the increase in consumption of resources and energy associated with urbanization, irreversible environmental degradation, or even the existence of pollution havens (6, 7). This debate about the relationship between economic development and the environment is decades old, and recent empirical work suggests that factors other than income, such as governance, regulation, and technology diffusion, may drive environmental quality (8–11). In short, past literature is inconclusive of whether and how urbanization has a clear positive or negative effect on the environment.

Much has been written about the demographic characteristics of contemporary urbanization at regional and global scales (12, 13). Less has been written about the interactions between the social and the physical dimensions of urbanization and the bidirectional feedback between urbanization and global change. The study of the physical component of urbanization—the conversion of land cover to urban uses—is not well understood, especially at global scales. Most of our understanding of urbanization as a land change process is based on individual case studies of cities or metro regions (14). What is becoming clear from these case studies is that there are significant differences in urbanization processes among regions and countries, and even within countries; urbanization is not a homogeneous process. Identifying these differences, as well as their commonalities, is critical for sustainability because different forms of urbanization have different impacts on the local and global environment. The spatial configuration of urban land use, urban processes, urban form, and the rate and scale of urbanization determines many of the interactions between urban areas and the environment.

The aims of this review are to discuss the key characteristics of contemporary urbanization, with an emphasis on urban land-use change, and to identify their drivers. We draw on the planning, urbanization, and climate change literatures and make recommendations for win-win strategies for bundling rapid urbanization and sustainability. In Section 2, we describe the major characteristics of contemporary urbanization. The purpose is to identify the multiple and concurrent changes in urban areas to develop a more complete understanding of the dynamics of urbanization trends and their implications for the environment. The effects of urbanization on hydrologic systems, biodiversity, climate change, and biogeochemical cycles are not discussed in this review. Rather, we focus our discussion on the impacts of urbanization on land cover conversion. Section 3 looks at the drivers of urban growth and specifically focuses on nondemographic factors. We view a discussion of nondemographic drivers of urbanization as important for three reasons. First, the nondemographic drivers of urbanization play a significant role in determining demographic changes, and yet the connections are often not explicitly discussed. Second, although their effects are locally specific, nondemographic drivers operate at multiple spatial scales and are not contained within an urban area. Third, these nondemographic drivers interact and can amplify their individual impacts on urbanization processes. Section 4 describes the opportunities for bundling urban development initiatives and climate mitigation and adaptation strategies to create synergies to transition to sustainability. We focus on urban land-use planning and ways in which it can foster urban forms that are more sustainable. We conclude Section 4 with an analysis of greenhouse gas emissions under different scenarios of urbanization and population growth over the next 40 years. Finally, Section 5 summarizes the findings of this synthesis and suggests directions for future research.

Sustainability: meeting the needs of the present generations without compromising the capacity of future generations to meet their needs

Institutions: formal rules and informal constraints that affect strongly or weakly, directly and indirectly everyday behavior and choices in market and nonmarket settings

Governance: the process of governing, such as top-down administration through national level or bottom-up from community organizations

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2. CHARACTERISTICS OF CONTEMPORARY URBANIZATION

City: a subset of an urban area, defined by political administrative boundaries

Agglomeration: the geographic concentration of economic activity that is observed across scales—the formation of urban centers, industrial clusters, hierarchical systems of cities

Twenty years ago, Kates et al. (15) wrote that we live in a special period in history, calling it the "Great Transformation," one where "the scales, rates, and kinds of environmental changes have been fundamentally altered as humanity has passed through an era of rapid population growth . . . ." We are now in a second great transformation. Humanity crossed a milestone in 2008 when the global urban population exceeded the rural population for the first time in history. Short of major health epidemics and natural hazards that affect large population centers, a growing proportion of world population will live in urban areas for the foreseeable future.

This trend is a departure from most of human history when populations were mainly rural and lived in smaller urban settlements. This new era of urbanization—as both a demographic and land change process—has characteristics that differentiate it from other periods in history. First, the scale of urbanization is extraordinary; cities are bigger than at any other time in terms of their physical extents, population sizes, economic importance, and environmental impacts. Second, the rate at which populations and land cover are becoming urban is faster than at any other time in history. Third, the location of urbanization is changing; the urban transition in Europe and South America occurred in the 1950s through the 1970s. Urban growth in the coming decades will take place primarily in Asia and Africa and expand into agricultural lands, forests, and other natural land covers. Fourth, the form of urban settlements is changing. Urban areas have historically been compact and concentrated populations. Urban areas are now increasingly expansive and peri-urban with significant differences between developed and developing countries. Fifth, urban function is increasingly specialized, and this, in turn, has differentiated its effects on the urban labor force, urban lifestyles, and the environment.

There is perhaps a sixth characteristic of contemporary urbanization: The aforementioned trends interact and amplify their individual effects. These characteristics are interrelated, and the processes that drive them co-evolve. Individually, these characteristics suggest a significant break from periods of rapid urbanization in the past; together, they represent a profoundly new era of urbanization.

2.1. Changes in Scale

Some of the most defining attributes of the new era of rapid urbanization are the absolute size of urban areas in terms of their increased population, their physical extent, and the number of urban areas. For individual cities, urban populations have reached incomparable scales.

At the start of the 1800s when the world population was around one billion people, Beijing was the only city with a population of one million or greater. One hundred years later, at the turn of the twentieth century, there were 16 cities with populations of one million or greater. Forward another hundred years to 2000, and there were 378 cities with populations of greater than one million (16). In India alone, there are now 40 cities with populations of 1 million; in China, there are more than 100. By 2025, there will be about 600 cities of one million or more worldwide (**Table 1**).

Not only are there more urban settlements, but there are more very large urban agglomerations. In 1900, there were no cities with a population of 10 million. By 1950, the New York City metropolitan area became the first urban area to reach a population of 10 million (16). Tokyo was the first city to have a population of 10 million in 1962. Today there are 19 urban agglomerations with populations of 10 million or more, with Tokyo-Yokohama at the top of the list with a population of 35.7 million; the city of Tokyo has 12.8 million people (16).

For years, it was assumed that urban areas were less important in global change studies because total global urban land cover was a relatively small proportion of Earth's terrestrial surface—less than 2% (17). Although there

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Table 1 City size by population and geographic distribution[a]

City size by population	Geographic region	1950		1975		2000		2015		2025	
		Number of cities	Percentage of total	Number of cities	Percentage of total	Number of cities	Percentage of total	Number of cities	Percentage of total	Number of cities	Percentage of total
10 million or more											
	World	2		3		15		24		27	
	Africa	0	0.0	0	0.0	1	6.3	3	12.5	3	11.1
	Asia	1	50.0	1	33.3	8	50.0	13	54.2	16	59.3
	Europe	0	0.0	0	0.0	0	0.0	2	8.3	2	7.4
	Latin America and the Caribbean	0	0.0	1	33.3	4	25.0	4	16.7	4	14.8
	Northern America	1	50.0	1	33.3	2	12.5	2	8.3	2	7.4
	Oceania	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5 to 10 million											
	World	5		15		28		35		48	
	Africa	0	0.0	1	6.7	2	7.1	2	5.7	8	16.7
	Asia	1	20.0	6	40.0	18	64.3	21	60.0	25	52.1
	Europe	3	60.0	3	20.0	3	10.7	3	8.6	3	6.3
	Latin America and the Caribbean	1	20.0	3	20.0	3	10.7	4	11.4	4	8.3
	Northern America	0	0.0	2	13.3	2	7.1	5	14.3	8	16.7
	Oceania	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1 to 5 million											
	World	71		163		334		460		524	
	Africa	2	2.8	8	4.9	34	10.2	59	12.8	73	13.9
	Asia	27	38.0	73	44.8	166	49.7	245	53.3	291	55.5
	Europe	20	28.2	35	21.5	49	14.7	47	10.2	47	9.0
	Latin America and the Caribbean	7	9.9	17	10.4	42	12.6	60	13.0	63	12.0
	Northern America	13	18.3	28	17.2	37	11.1	43	9.3	44	8.4
	Oceania	2	2.8	2	1.2	6	1.8	6	1.3	6	1.1
500,000 to 1 million											
	World	120		237		399		488		551	
	Africa	5	4.2	18	7.6	39	9.8	61	12.5	84	15.2
	Asia	50	41.7	93	39.2	192	48.1	247	50.6	275	49.9
	Europe	44	36.7	69	29.1	74	18.5	79	16.2	82	14.9
	Latin America and the Caribbean	4	3.3	25	10.5	55	13.8	57	11.7	63	11.4
	Northern America	17	14.2	28	11.8	39	9.8	42	8.6	45	8.2
	Oceania		0.0	4	1.7		0.0	2	0.4	2	0.4

[a]Source: Reference 16.

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are estimates of urban population growth at national and global scales, there is little understanding of how urban land cover has or will change as a result of urban population growth. Satellite-based studies calculate urban land cover at 3% to 5% of total land surface, but there remain significant uncertainties with mapping urban land cover and urban expansion at global scales (18). In particular, there are greater variations in estimates of urban area for Asia than other regions of the world (19).

Individual case studies reveal that urban areas have reached a physical size unparalleled in history. The urban extent of Tokyo-Yokohama covers 13,500 km^2, an area that is bigger than Jamaica (11,000 km^2). Massive urban land-use change has occurred all around the world. In the Nile Delta, approximately 3,000 km^2 of land have been converted to urban uses over a 30-year period from 1970 to 2000 (20). In Puerto Rico, urban sprawl affects 40% of the island and one-quarter of the island's prime agricultural land (21). During a 10-year period from 1990 to 2000, urban areas in China expanded by more 8,100 km^2, an area about the size of Puerto Rico (22).

2.2. Changes in Rate

A second characteristic of contemporary urbanization is the rapidity with which urban populations are growing and land cover is being converted to urban areas. High urbanization levels are a relatively recent occurrence. It took all of history until 1960 for the world urban population to reach one billion, but only 26 years to reach two billion (**Table 2**). Since then, the time interval it takes to add an additional one billion urban dwellers is decreasing, indicating an increase in the rate of urban population growth. In fewer than 100 years, the urban population will grow from one billion to six billion.

Rapid urban population growth is a recent phenomenon. Levels of world urbanization from the first century until the middle of the nineteenth century ranged between 4% and 7%, and rates of urban population growth were extremely low. Since the 1950s, global magnitudes and rates of urbanization have been astounding. At early stages of the urban transition, where levels of urban population are low, rapid urbanization depends on high annual rates of population change. The urban population rate of growth is slowing down globally (19). From 1950 to 2007, it averaged at 2.6% per year—an average that is expected to drop to 1.8% between 2007 and 2025; at this rate, urban population would double in 38 years (16). But as the national percentage of urban population becomes larger, high annual rates of urban population growth are not required for high magnitudes of urban population change (**Figure 1**, see color insert). For example, across all world regions, urban population annual growth rates are highest closer to the 1950s and have steadily declined since then (**Figure 1**). But even with declining growth rates, the absolute magnitudes of increase of urban populations is at all time highs. **Figure 2** (see color insert) contrasts the urban population growth rates for India and China with the proportion of urban population in each country across time. For both countries, the urban population growth rate ranged from about 2% to 5% between 1950 and 1970, with significant variability. Since the 1990s, the trend is declining; circa 2010, these rates were between 2% and 3%. However, the proportion of the population that is urban is growing in both countries. By 2050, more than 70% and 50% of the population in China and India, respectively, will be urban. In the future, urban population growth rates are expected to be

Table 2 Global urban population and time intervals for the addition of 1 billion urban residents

Year attained	Global urban population	Number of years
1960	1 billion	5000+[a]
1986	2 billion	26
2003	3 billion	17
2018	4 billion	15
2031	5 billion	13
2044	6 billion	13

[a]The longest history of urban population growth dates back to 3,000 BC (147). This analysis extends an earlier study by Satterthwaite (23).

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twice as high as the world's population growth as a whole (16). Other analyses of the UN population data have similarly concluded that the rate and magnitude of urban population growth is unparalleled (12, 23).

As urban populations grow, urban land expands upward or outward to accommodate the new population. For most of history, the rate of urban land expansion was low, and the physical extent of cities grew slowly. Walled cities were common from the fifth to the sixteenth century in Europe and China, and these barriers served to contain the growth of the city as well as physically separate the city from its environs (24, 25). For example, the circumference of Beijing was approximately 28.6 km for more than 300 years from the mid-1200s through the mid-1500s (26). Contemporary cities have few, if any, material boundaries, and many are expanding unencumbered. Some have shown that in parts of the United States and Europe, urban land area grows in proportion to urban populations, and a scaling relationship exists between the two (27, 28). Using data for 108 cities from two satellite-based studies of urban land expansion (29, 30), we found that the rate of urban land expansion to be faster than the rate of urban population expansion for most cities, suggesting that these urban areas are becoming more expansive than compact (**Figure 3**).

2.3. Changes in Location

Over most of the last 2,000 years, the world's largest cities have primarily been in the Eastern Hemisphere (**Table 3**). Not until 1800 did the first European city appear as one of the top five largest cities. From 1900 to 1950, the largest cities were located in Europe and the United States. In the new era of urbanization, the largest cities will be in Asia and South America. Between 2007 and 2050, the world urban population is expected to increase by more than 3 billion. This scenario assumes a reduction in fertility rates in developing countries; if fertility remains at current levels, then urban populations may increase by as much as

Table 3 Largest world cities from the year 100 to 2025

Rank	100[a]	1000[a]	1500[a]	1800[a]	1900[a]	1950[b]	2000[b]	2025[b]
1	Rome	Cordova, Spain	Beijing, China	Beijing, China	London, United Kingdom	New York, United States	Tokyo, Japan	Tokyo, Japan
2	Luoyang, China	Kaifeng, China	Vijayanagar, India	London, United Kingdom	New York, United States	Tokyo, Japan	Mexico City, Mexico	Mumbai, India
3	Seleucia, Iraq	Constantinople	Cairo, Egypt	Guangzhou, China	Paris, France	London, United Kingdom	New York, United States	Delhi, India
4	Alexandria, Egypt	Angkor, Cambodia	Hangzhou, China	Edo (Tokyo), Japan	Berlin, Germany	Shanghai, China	São Paulo, Brazil	Dhaka, Bangladesh
5	Antioch, Turkey	Kyoto, Japan	Tabriz, Iran	Constantinople (Istanbul), Turkey	Chicago, United States	Paris, France	Mumbai, India	São Paulo, Brazil

[a]See Reference 16.
[b]See Reference 147.

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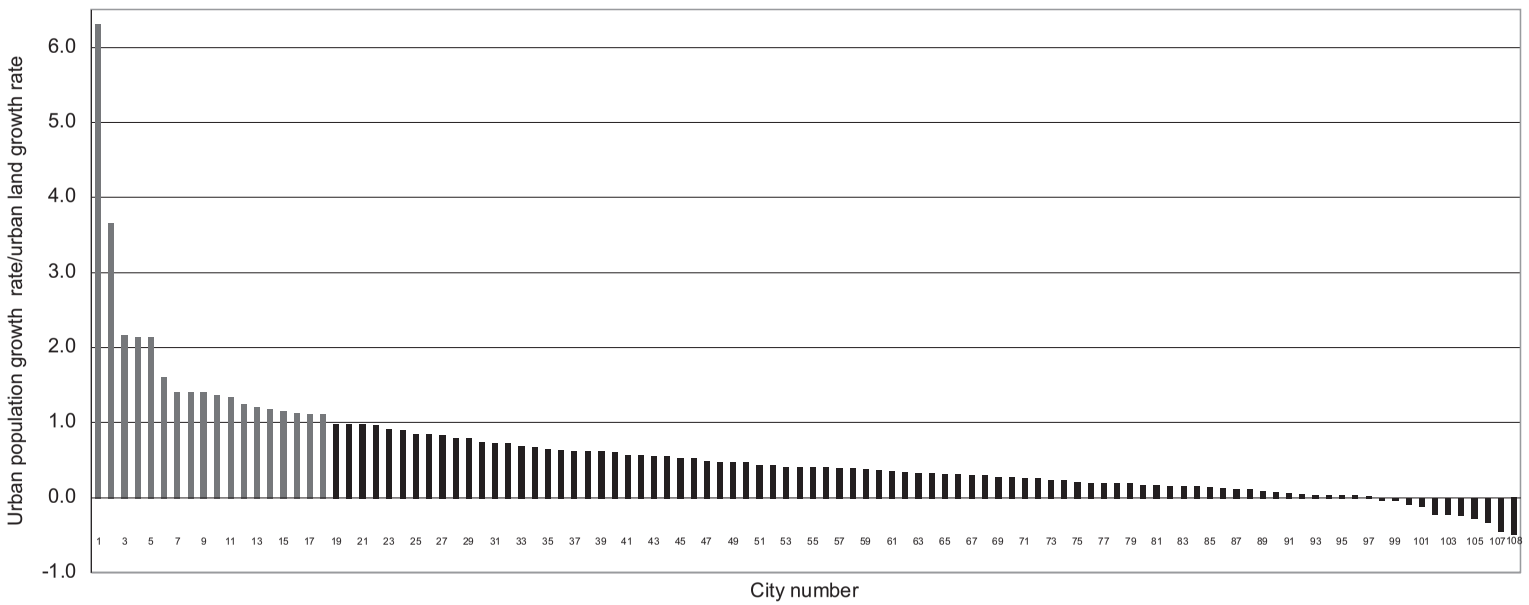

Figure 3

Ratio of urban population growth to urban land growth. Eighty-eight case study cities are shown from Reference 29, where growth rates were calculated with data from the mid-1980s and 2000. Twenty case studies, marked with an asterisk, are shown from Reference 30, with growth rates calculated by data from 1990 and 2000. Values greater than one (*gray*) indicate cities where urban population is growing faster than urban land expansion (compact growth). Values less than one (*black*) indicate cities where urban land expansion is at a faster rate than urban population growth (expansive growth).

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City number, name, and ratio of urban population growth rate to urban land growth rate

1 Kuwait City, Kuwait 6.30	**28** Kuala Lumpur, Malaysia 0.80	**55** Accra, Ghana 0.41	**82** Springfield, United States 0.15
2 Montreal, Canada 3.65*	**29** Houston, United States 0.79	**56** Ankara, Turkey 0.41*	**83** Harare, Zimbabwe 0.15
3 Phoenix, United States 2.16*	**30** Guadalajara, Mexico 0.74	**57** Bandung, Indonesia 0.40	**84** St. Catharines, Canada 0.15
4 Warsaw, Poland 2.15*	**31** Port Sudan, Sudan 0.73	**58** Baku, Azerbaijan 0.38	**85** Leshan, Chian 0.14
5 Wuhan, China 2.13*	**32** Casablanca, Morocco 0.73	**59** Madrid, Spain 0.38*	**86** Anging, China 0.13
6 Cebu, Philippines1.60	**33** Guangzhou, China 0.68	**60** Baltimore, United States 0.	**87** Moscow, Russia 0.11
7 Aswan, Egypt 1.41	**34** Mumbai, India 0.68	**61** Madrid, Spain 0.35	**88** Bacolod, Philippines 0.11
8 Monterrey, Mexico 1.41*	**35** Brasilia, Brazil 0.64*	**62** Astrakhan, Russia 0.33	**89** Philadelphia, United States 0.09
9 Banjul, Gambia 1.40	**36** Ulan-Bator, Mongolia 0.64	**63** Songkhla, Thailand 0.33	**90** Chinju, Republic of Korea 0.08
10 Guaruja, Brazil 1.36	**37** Bamako, Mali 0.62	**64** Tel Aviv-Jaffa, Israel 0.32	**91** London, United Kingdom 0.06
11 Ribeirao Preto, Brazil 1.34	**38** Algiers, Algeria 0.61	**65** Rajshahi, Bangladesh 0.32	**92** Wien, Austria 0.05
12 Nairobi, Kenya 1.25*	**39** Washinton, DC, United States 0.61*	**66** Kolkota, India 0.31	**93** Palermo, Italy 0.04
13 Ibadan, Nigeria 1.21	**40** Bangalore, India 0.60*	**67** Jaipur, India 0.30	**94** Warszawa, Poland 0.04
14 Kingston, Jamaica 1.18	**41** Cairo, Egypt 0.57	**68** Vijayawasa, India 0.29	**95** Jequie, Brazil 0.03
15 Sanaa, Yemen 1.16	**42** Zugdidi, Georgia 0.57	**69** Jalna, India 0.28	**96** Yiyang, China 0.03
16 Addis Ababa, Ethiopia 1.13	**43** Caracas, Venezuela 0.55	**70** Fukuoka, Japan 0.27	**97** Akashi, Japan 0.02
17 Sacramento, United States 1.11*	**44** Ipoh, Malaysia 0.55	**71** Hyderabad, India 0.26	**98** Sheffield, United Kingdom -0.02
18 Tijuana, Mexico 1.10	**45** Manila, Philippines 0.53	**72** Saidpur, Bangladesh 0.26	**99** Ilheus, Brazil -0.02
19 Ahvaz, Iran 0.99	**46** Gorgan, Iran 0.53	**73** Victoria, Canada 0.23	**100** Leipzig, Germany -0.08
20 Tebessa, Algeria 0.97	**47** Minneapolis, United States 0.48	**74** Coimbatore, India 0.23	**101** Milano, Italy -0.11
21 Dongguan, China 0.97*	**48** Malatya, Turkey 0.47	**75** Alexandria, Egypt 0.20	**102** Ndola, Zambia -0.20
22 Sao Paulo, Brazil 0.96	**49** Chengdu, China 0.47*	**76** Cincinnati, United States 0.19	**103** Budapest, Hungary -0.21
23 Calgary, Canada 0.91*	**50** Modesto, United States 0.47	**77** Changzhi, China 0.19	**104** Shimkent, Kazakhstan -0.23
24 Teheran, Iran 0.90	**51** Kanpur, India 0.43	**78** Puna, India 0.19	**105** Yerevan, Armenia -0.27
25 Hanoi, Vietnam 0.85*	**52** Ouagadougou, Burkina Faso 0.42	**79** Paris, France 0.19	**106** Pittsburgh, United States -0.32
26 Marrakech, Morocco 0.85	**53** Guangzhou, China 0.41*	**80** Le Mans, France 0.16	**107** Pusan, Republic of Korea -0.44
27 Alexandria, Egypt 0.84*	**54** Castellon de la Plana, Spain 0.41	**81** Kigali, Rwanda 0.16	**108** Prague, Czech Republic -0.48*

Figure 3

(*Continued*)

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5 billion over the next 40 years. The majority of this growth will occur in Africa and Asia, where current urbanization levels are low at 40% and 45%, but the increased scale of urbanization will be most extraordinary in China and India.

Over the next two decades, the urban population in China is expected to exceed one billion, an increase of 400 million, and result in the creation of at least 30 cities of one million (16). During this same period, the total population of India is projected to surpass that of China, with its urban population nearly doubling from today's 350 million to 611 million and with an addition of 26 cities of one million. The combined urban population growth in China and India is expected to be more than 700 million over the coming two decades. Although demographers warn of the uncertainties around these national level population forecasts (12) and city size projections (31), the current and expected urban transitions in China and India represent the largest scale of urbanization the world has ever experienced. Put into a global context, by 2030, nearly one of every three of the world's urban residents will reside in either China or India (**Figure 4**, see color insert).

Historically, urban settlements developed near fertile agricultural lands and water bodies. Contemporary urban settlements are now in the far corners of Earth and have transformed every type of ecosystem. The global natural resource supply and distribution chains have enabled large settlements to develop in arid environments and other resource-constrained regions. The rise and extensive development of cities in the Middle East over the past 20 years has been enabled by the development of desalinization plants; in 2005, 70 of the 100 largest desalinization plants proposed, in construction, or in operation in the world were in the Middle East (32). In 1975, the population of Dubai was only 183,000; by 2009, its population had increased ninefold to over 1.7 million.

Whereas in 1950 the geographic distribution of large cities was more evenly distributed worldwide, a majority of the largest cities—and more than half of the world's cities with populations of 500,000 and greater—will be located in Asia (**Table 1**). The changing geography of urbanization is expected to have varying impacts on ecosystems and land cover. Urbanization may result in households climbing up the "energy ladder" and switching from fuelwood to modern fuel sources, thereby reducing pressure on forest cover (33). Others suggest that urbanization will reduce pressure on forests owing to a shrinking rural population and the extent to which these populations cause deforestation (34). Irrespective of rural consumption patterns, the physical expansion of urban areas will transform land cover and habitat. The urban transformation of Singapore has resulted in a 95% loss of habitat and up to 87% extinction rates for various forest taxa (35). Today, one-quarter of the world's protected areas are within 17 km of a city with a population of 50,000; by 2030, the distance will decline to 15 km (2). In the United States, housing development growth rates near protected areas are higher than national averages and threaten their conservation value (36). Depending on urban population densities and the rate of urban land expansion, an additional 3 billion urban dwellers may require from 400,000 km^2 to 1,429,000 km^2 of new urban land, equal to an area four times the size of Germany (37).

2.4. Changes in Form

Although most studies of urbanization and the environment have focused on defining the rate and scale of urban land change, fewer studies have evaluated the changing form of urban areas. Yet, urban form—or urban morphology—is central to the impact of urbanization on the environment. Urban form has been studied for more than a century within the fields of urban planning, economics, geography, and sociology, which have developed the foundations about spatial land-use theory and models (38, 39). Since the 1960s, work on urban growth and morphology have been an important subject of interest—not only for geographers and economists (40–42)—but also for natural scientists and physicists (43).

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The past 125 years have thus resulted in a wealth of knowledge on the spatial form of urban systems. We now view the spatial configuration of urban areas as a path-dependent process that is a reflection of past decisions as well as a manifestation of current socioeconomic and political processes; some of these include planning, transportation costs, agglomeration economies, and market prices. The interaction between these processes and the landscape is important in shaping urban form in developed and developing countries. However, poverty, social inequality, and marginalization in developing countries create differentiated outcomes in urban form. This is a relevant issue given the rapid pace of urbanization in those countries and the high concentration of future population growth expected in those settlements. Still, we also know that urban systems are complex adaptive systems, hierarchically structured at several levels. Urban systems follow power and scaling laws in their distribution of populations and area extents. We observe scaling laws at different geographical scales, from the national system of cities (44) to urban clusters within metropolitan areas (45, 46).

Up until recently, urban land-use change was primarily explored through one-dimensional measures of area extent or rate of land cover change. However, it has been shown that aggregate measures of urban extent and growth rates do not quantify critical components of the urban land change process, such as the degree to which urban expansion is compact or leapfrogging (47). Quantifying and describing changes in urban land-use patterns beyond its extent and cumulative growth rates requires an explicit look at the landscape mosaic. Increasingly, urban land-use change studies use spatial pattern metrics that originate from the field of landscape ecology (48–50). Many of the indices that have been developed to characterize the complexity, shape, and configuration of landscapes (51) are particularly useful to the study of urban morphology.

Studies of urban morphology and rates of urban expansion show that contemporary urbanization is increasingly disperse and expansive (29, 52). For centuries, cities were characterized by compact living. Through historical data, we know that the U.S. system of cities progressed from small, compact, dense, coastal developments during the colonial era to larger, compact, dense, and further inland development by the middle of the twentieth century. Since World War II, urban densities in the United States have dropped as populations moved further away from the urban centers, and urban growth patterns have become more expansive, which, in turn, has lead to high-consumption levels of land, water, and fossil fuels and adversely impacted ecosystem services (53, 54). Although these automobile-centric patterns of low-density suburban development—what Leichenko & Solecki call "consumption landscapes" (55)—have been observed in the United States for more than half a century, they are a relatively new, but increasingly common, phenomenon around the world. Empirical studies have documented the rise in this type of expansive development in many countries, including India (56), China (57), Mexico (58), Brazil (59), Canada (60), and Australia (61).

In addition to widespread suburbanization, which is dominated by single-family residential development, there is also an increase in the phenomenon of peri-urbanization (62, 63). The peri-urban interface refers to spatially and structurally dynamic transition zones where land use, populations, and activities are neither fully urban nor rural. Although it is often assumed that populations and economic activities can be sharply divided between urban (industrial) and rural (agricultural), peri-urban households may be multispatial, with some family members living in rural areas but not employed in agricultural activities and others living in urban areas but engaged in agriculture (64). As such, peri-urban areas are hybrid landscapes: a juxtaposition of traditional and rural with modern and urban. In these areas, there is an intense interaction between rural and urban economies and lifestyles. Peri-urbanization is usually initiated by an influx of nonlocal capital in industries or housing development and

can take place as far as hundreds of kilometers from the urban core. Peri-urbanization is occurring throughout the world, but some researchers suggest that it is the dominant form of urbanization in East Asia, and this style of urban development presents new challenges for planning and governance (65, 66).

2.5. Changes in Urban Life and Urban Function

The aforementioned changes in the physical and demographic characteristics of contemporary urbanization are paralleled by significant changes in urban function and urban life. The term urban primacy refers to the degree to which a city's population and economic function dominates other cities in a country. A primate city is the population, economic, and cultural hub of a country. Bangkok is an excellent example of a primate city: Its population of 6.9 million is 25 times that of the second largest city, and its economy generates nearly half of the country's gross domestic product (GDP). Buenos Aires is another example of extreme urban primacy: It is home to one-third of Argentina's total population. According to empirical evidence, the degree to which a country's populational and economic resources is concentrated in a single city is a function of domestic political stability and the country's participation in international trade (67). However, historical concentration of political and economic power in countries' capital cities continues to strengthen urban primacy in some major cities. It is equally important to consider the function of urban areas in the subnational geographic space. Urban areas are economic, social, cultural, and political centers that also serve as hubs for regional development. They interact dynamically with rural and peri-urban areas through the exchange of goods and services, and they create stability to regional structures. A third level of urban function worth considering is intraurban. The dynamic interactions of economic, social, and cultural processes within the urban space are key determinants of the scale, rate, and geographic patterns of urbanization.

In terms of urban life, there are clear indications that family dynamics are changing in this new era of urbanization. Family size is shrinking, and in cultures where multigenerational housing was the norm, two-person households are now more common. There is also a stronger social and economic link between the urban and the rural. This is in part due to the peri-urbanization process whereby some family members reside in the city and others in the countryside. Nevertheless, the point is that the division between urban and rural is less distinct today. Another change in urban living is the embrace of Western styles of architecture and urbanization, which are resource intensive and often not adapted to local climates. The North American suburb has gone global, and car-dependent urban developments are increasingly the norm. These patterns of sprawled development have been associated with increasing social segregation and reduced community participation, less social involvement, and a disruption of community "boundedness" (68). The international debate on climate change creates a useful framework to consider the real impact of the current Western model of consumption and lifestyle exported through globalization—even to the most remote regions of the world.

As more world regions move further along their urban transition, Western-style diets are being adopted globally. Asian diets have already shifted away from staples and are moving toward meat and dairy products, vegetables, fruit, fats, and oils (69). It is theorized that globalization (through increased trade and flow of products, services, and information), mass-media marketing, the prevalence of multinational food corporations in food supply chains, and the increasingly close connections in the lives of urbanites are the main forces driving the phenomenon (70). Obesity is considered an emerging epidemic in the developing world, and concerns regarding additional adverse health effects and the health inequities of urban diets in developing countries have started to materialize (71, 72). Recent research has

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documented the impact of the built environment on lifestyles and suggests that the urban form can reduce incentives and possibilities for physical exercise within urban areas (73). The research also shows a strong relationship between the mix of land uses and obesity (74).

We know that, viewed as a whole, urban areas show significantly higher levels of wealth because of higher productivity levels. However, a big challenge in urban research is the lack of measures of GDP growth at the urban scale. It is estimated that 30% of national GDP in the United Kingdom, Sweden, Japan, and France is accounted for by London, Stockholm, Tokyo, and Paris, respectively (75). Globally, metro areas drive their national economics, but there are significant disparities in the GDP per capita between and within the world's urban areas (75, 76). There is even a bigger disparity between the wealthy and the poor in cities, and this disparity is exacerbated by the scale and rapidity of change. Economic development and improvements in well-being are only part of the urbanization story: Worldwide, more than 900 million people live in informal settlements, with most living under life- and health-threatening conditions (77, 78). Put another way, approximately one out of three urban dwellers worldwide lives in slum conditions, and this ratio is expected to increase in the future. In light of their importance locally and regionally, and considering their size globally, the discussion of sustainability needs to incorporate approaches that include and consider informal settlements.

3. DRIVERS OF CONTEMPORARY URBANIZATION

Interacting processes that operate across multiple spatial scales are driving the rapidity, scale, and geographic reach of contemporary urbanization. These drivers are not limited to the urban boundary. Our understanding of the drivers of urban land expansion has developed significantly beyond population growth and demographic trends. In this discussion, we focus on three nondemographic drivers that interact, amplify changes in urban areas, and are transforming contemporary patterns of urbanization: footloose international capital, governance and institutional structures, and agglomeration forces.

3.1. Footloose Global Capital

International capital is shaping the expansion of urban areas in three ways. First, international real estate developers and property management firms have become a major presence, contributing to the development of high-rent industrial and residential facilities, built in a geographically indistinguishable "global modern" style that can be found anywhere from the San Francisco Bay Area to Bengaluru (79, 80). Second, the space, infrastructure, and human resource demands of multinational firms—particularly technology and science industries—have required the construction of facilities with superior physical infrastructure and particular amenities (81, 82). These may include broadband Internet, uninterrupted electrical power, water, air conditioning and computer and telecommunications room cooling facilities, and security. Third, the influx of international capital has changed the landscape of consumption in urban areas around the world, as educated workers flow into the city after returning from extended employment opportunities in the United States and Europe, and as rising worker incomes increase the demand for higher-end, and often imported, consumer goods and services (83). The influx of international capital has produced dispersed urban growth as well as unplanned and uncoordinated urban expansion in cities around the world from Warsaw (84) to Shanghai (85).

The impact of international capital on local development and economies is not always positive. For example, the rapid expansion of industries in urban and peri-urban areas has lead to the creation of slums to accommodate workers of those industries. Injections of foreign capital are also driving changes in housing and lifestyles that conflict with traditional ways of living. Large tracts of land are developed as

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special economic, export, and industrial zones with the purpose of developing domestic industries and attracting developers and international corporations. India has 101 special economic zones in operation, and nearly 600 more have been approved (86). In China, it is estimated that 6% of the country's arable land was converted to development zones between 1986 and 1995 (87). Thus, rapid urbanization in many regions is at the expense of prime farmland, resulting in governments buying or leasing agricultural land abroad—what some call a "global land grab" (88).

3.2. Governance

Urban governance has moved away from a vertical and hierarchical system of government toward a horizontal network-oriented framework with greater emphasis on democratic participation and decentralization. This has allowed for the participation of new actors from the private and social sectors, which, in turn, is expected to lead to new cooperation processes and the establishment of new negotiation systems (89). There are common characteristics in the new urban governance and institutional structures but also regional differences. One common element of new urban governance that affects the path and rate of urbanization throughout regions is the effort from national, state, and provincial governments to transfer management responsibilities for public services to local governments without transferring adequate financial resources to take over those responsibilities. Some argue that the increased participation in urban governance from the private sector and civil society reduces government responsibility for and accountability of urban development, particularly in the supply of public services (90, 91).

Since the 1990s, new processes of decentralization and regionalization have affected the institutional landscape in the European Union (EU): the wave of territorial reorganization and major transformations of European states; a new division of labor between states, local and regional authorities, and decentralization; and regionalization or federalization (91). Urban areas are important elements in addressing those transformations and the challenges of globalization. Urban areas gained increased autonomy with regard to their national institutional frameworks, and the EU promoted sustainable urban development and the implementation of the partnership principle, seeking successful urban governance (92). The reforms of urban institutions were aimed at optimizing the delivery of public services, at generating a collective dynamic at the urban level, and at creating projects that would bring together a large number of local actors from diverse areas of civic society (90).

New urban governance regimes have had different effects in other regions. Despite a tradition of seeking a broader participation of civil society, urban governance in North America lacks the financial and institutional support from national governments, and there is no supranational institution similar to the EU. Urban communities in the United States have diverse, decentralized, and fragmented models of developing and financing urban infrastructure and public services. Urban policy makers are now negotiating with neighboring communities, competitive markets, and citizens in a fragmented governance system (93). Urban areas have increasingly relied on state governments for assistance in addressing major problems, and their revenue structure has increasingly become dependent on user fees and charges. There has been an explosion of public authorities and special districts since the late 1950s. Urban areas have outsourced the provision of public services to authorities and special districts that operate separately from the municipal government while simultaneously charging citizens for these services; these include water and sewer services, mass transit, bridges, tollways, flood control and drainage, housing, and redevelopment (94). These new arrangements have fundamentally changed the process of urbanization by reducing the effectiveness of local planning and authorities in shaping urban development.

Another significant change in urban governance and institutions in the United States

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that has affected the pattern of urbanization is the increase in the formation of "private governments" through homeowners' associations (HOAs) during the past 35 years. The number of people living in HOAs climbed from 2 million in 1970 to 58.8 million in 2007 (93). Many HOAs have infrastructure responsibilities, but their capacity for integrated and coordinated action in a metropolitan area is severely limited. Thus, urban governance in the United States is confronted by fragmented financial and policy-making systems, and the current models of urban governance have dramatic consequences on the physical expansion of urban areas (75). Unfortunately, most of the discussion about urban sprawl in the United States has been detached from the discussion of urban governance. The challenge for urban communities is that the fragmented structure of urban governance is an obstacle to creating consensus among a diverse array of actors needed to integrate plans for urban sustainability.

In developing countries, urban governance strongly relates to problems of political process and limited human, technical, and financial resources to direct urban development. The changes, driven by international capital, are being played out in the context of the developing countries' weak regional planning infrastructures, which historically have focused on their central cities (95). Changes in urban governance and institutions, combined with the relaxation of economic regulations, are enabling international capital, institutions, and actors to accelerate the process of planning privatization and economic segregation. Foreign capital is effectively trumping public regional planning owing to changes in urban governance and is accelerating the rate of urban growth while changing the basic structure and function of urban areas. The results are new urban artifacts, such as shopping malls, large commercial spaces, industrial estates, and gated communities (96).

Although gated and restricted access communities have long been a presence in industrialized cities, they have emerged as a common form of urbanization in developing-country cities and created with them new forms of social exclusion (97, 98). Conflicts are also arising in peri-urban areas because of competing interests between international firms and local development. National or state governments identify land for international investment and urban development but often exclude local municipalities in the decision-making process and expect them to maintain the projects (84).

The lack of inclusive urban governance has aggravated the urbanization process in countries characterized by social and physical marginalization of large numbers of urban inhabitants, poverty, and environmental degradation, with sharp contrasts between the formal and informal urban space, the rich and the poor, the legal and the illegal. Yet, despite the dire situation of the poor and the severe limitations of urban governance, some of the most interesting and comprehensive initiatives of urban governance emerge from countries, such as Brazil and Thailand (99–101).

3.3. Institutions

Closely related to the issue of urban governance are the roles of institutions that define the scale, rate, and form of urbanization. Here we highlight three major—and often interacting—institutions that are central to shaping the contemporary urbanization process: the real estate market, spatial planning, and the voluntary sector. The relations of power among urban actors significantly influence the urban space resulting from those interactions. For example, local real estate markets have traditionally been a major institution in defining urban land-use patterns. Globalization has transformed the commercial property market from a local to an international industry (102). In Mexico, the influx of transnational corporations has created inefficiencies in the real estate market and intense competition for urban land and urban services (103). These market inefficiencies have lead to conflicts and contradictions in access to urban land and public services, thereby creating fragmented urbanization processes and the rapid spread of informal settlements in Mexican border communities.

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An important driver of the rate, scale, and pattern of urbanization are land-use plans developed by local authorities. Irrespective of nomenclature—comprehensive plans, master plans, general land-use plans, spatial plans, or regional plans—the primary purpose is the same: to determine and coordinate the location and arrangement of the built environment, infrastructure, and natural resources. Land-use planning tools, such as zoning, attempt to control the degree to which neighborhoods are single use (residential, commercial, or industrial), define residential and commercial density, affect transportation infrastructure, and encourage the conservation of green space.

Despite the potential power of spatial planning to direct the scale, rate, and form of urbanization, it has been incapable of controlling and orienting urban growth (104). More than 35 years ago, Blair (105) highlighted the deficiencies in urban planning approaches. More recent research questions the assumption that urban planning can impose order to the inherent complexity of the urbanization process (106). In the United States, urban plans have failed despite more than a century of progressive urban planning (107), and urban planning is increasingly decentralized and privatized (108). In developing countries, international master planning consultancies are emerging as powerful institutions that shape the new urban landscape. They are brought in at the behest of either local or national authorities and often through international competition. These consultancies are planning, designing, and building the new urban landscape around the world, with local planning institutions playing a relatively minor role.

Research over the past decade has also documented an increasing role of the voluntary sector and nongovernmental organizations in shaping the urban landscape, especially in helping urban communities mobilize resources to improve public services and social well-being. The role of the voluntary sector is promoted by international organizations, such as the World Bank and UN-Habitat, as an important step toward affecting urban governance and the form and scale of urbanization. In Bangkok, nongovernmental organizations (NGOs) have facilitated the development of community capacity to deal with environmental and urban problems in slums (101). NGOs also play an important role in reconciling informal and formal institutions addressing urban land management in developing countries (109).

3.4. Agglomeration Forces

The classic conceptualization of an urban area is that of a featureless plain, where land uses around a central business district are the result of the tension between declining land price gradients and increasing transportation costs (39). Our understanding of urban growth dynamics has increased considerably, in particular over the past 30 years, and we now have a more complex view of the factors that cause cities to expand spatially. One of the emerging themes is agglomeration forces, that is, factors that drive the geographic concentration of economic activity across different scales. Agglomeration manifests itself as clustering in neighborhoods (at the smallest scale), city formations (at a medium scale), and the core-periphery structure of nations (at the largest scale). This new economic geography distinguishes forces that disperse economic activity, such as land rents and immobile factors (e.g., land and natural resource), from forces that concentrate economic activity, such as forward and backward production linkages and labor markets (110). Important drivers of the urban growth of cities are economic activities that are in their geographic proximity and also national and international trade connections.

Many agglomeration drivers have been proposed and theorized. These include communication externalities, spatial competition, and increasing returns to scale in economic activity (111); urbanization (diversity in production activities) and localization (specialization in a single sector) economies (112); spatial competition through individual firm location decisions, large land developer decisions, and the availability of infrastructure (113, 114); local levels

of creativity and innovation (115); and the presence of multiple central business districts (116). There is still much to study about agglomeration processes, but it is already clear that clustering is a globally dominant trend that occurs at various scales (117).

In their evaluation of the empirical literature of the past 30 years, Rosenthal & Strange (118) find evidence of economic agglomeration forces of labor market pooling, input sharing, and knowledge spillovers. Furthermore, they also find that natural advantage, home market effects, consumption opportunities, and rent seeking all contribute to agglomeration. Although agglomeration forces are theorized to be at play in all urban areas, several examples elucidate the concepts. The presence of agglomeration forces at multiple scales can be observed in cases such as the regional development of the Manufacturing Belt (or Rust Belt) in the northeastern United States beginning in the nineteenth century, Italy's industrial north, and recently the Pearl River Delta in China; at the lower scale, agglomeration forces drove the formation of clusters like Route 128 in Boston and the Silicon Valley in Santa Clara County, California, and, more recently, in Bangalore, India (79).

Agglomeration across scales is now a dominant trend in driving urban growth. Its effects on urbanization from local neighborhood dynamics to global clusters of cities have significant implications on the local and global environment. Precisely because agglomeration is both a global and local phenomenon with no clear geographic boundaries, it accelerates and amplifies environmental changes, such as land conversion and habitat loss. The next section identifies how the drivers of urbanization affect consumption and production activities in urban areas and consequently climate change, biodiversity, natural habitats, pollution, and human well-being.

4. BUNDLING URBANIZATION AND SUSTAINABILITY

Given the enormous momentum underway that drives urbanization, the challenge confronting the Century of the City is not whether to urbanize but how to urbanize in ways that are more sustainable and with less environmental impact. Here, we discuss recent research on urbanization and global change in the context of sustainability.

4.1. Urbanization as a Trigger for Sustainability Solutions

Cities are agents of rapid change across a wide range of environmental, economic, and social systems. Agglomeration presents clear challenges for urban governance, but it also opens up opportunities for sustainability solutions. How can we better assimilate our knowledge on the new urban economic geography with our understanding of the bidirectional effects between urbanization and the global environment to articulate a vision of, and action plan for, sustainability? This section integrates empirical findings across different disciplines and suggests that increasing the number of urban agglomerations and the urban population within them can be part of the solution for global environmental challenges.

New research shows several sustainability advantages of cities and urban areas with larger populations (119). In addition to the economies of scale in terms of providing infrastructure, education, health care, and sanitation services, there is evidence of increasing returns to innovation and wealth creation as urban areas become larger (120). Assuming that a portion of that innovation will be directed toward responding to global environmental change, larger urban agglomerations have higher chances of providing solutions for sustainability through new technological tools and novel institutional arrangements. Using a scaling relationship between population and CO_2 emissions for U.S. metropolitan areas, Lobo et al. (121) find that a 1% increase in population (or economic output) is associated with only a 0.92% (or 0.79%, respectively) increase in CO_2 emissions. A production-based analysis estimates that urban areas contribute to approximately 30% to 40% of total

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anthropogenic greenhouse emissions (122). In contrast, a consumption-based analysis puts urban contributions at 60% of total, with a few wealthy cities contributing to a majority of the emissions.

Although agglomeration can present opportunities for sustainability solutions, expansive urban land conversion has significant and far-reaching environmental impacts. The scale, rate, and form of urban expansion affects local and regional temperature; precipitation patterns (123, 124); habitat and biodiversity (2, 125); ecosystem function (53); the loss of agricultural land (126, 127); travel demand (128); atmospheric changes (129); and the demand for water, energy, and agricultural resources (130), among many others. A recent study of global patterns of deforestation suggests that urban growth and the resulting changes in consumer demand may drive agricultural exports and deforestation (131). Thus far, the urbanization and global change research community has focused on cities as triggers of global environmental change and has identified pathways through which urban areas contribute to climate change with a focus on carbon emissions (132). Research has only recently begun to disaggregate cities and the urbanization process and attribute the source of the problem to underlying factors, such as urban form, urban lifestyles, consumption preferences and opportunities, and energy choices (133).

At the same time, as shown in the previous section, recent understanding from economic geography suggests that urbanization can facilitate the flow of ideas, and this, in turn, can trigger innovation and economic growth. Although the connection between geography and growth was understood early on, the functioning of cities was not central in the debates until recently (111). In the 1990s, the importance of cities came to the forefront of economic growth processes through more elaborate concepts on the effects of accumulation of technologies and ideas (134) owing to the increased capacity of higher flows of knowledge and information across agents (135). Since then, empirical results heavily underscore the importance of urban scale and density in increasing the productivity and creativity of firms and workers. This is an important point given the potential effects of a boost in technological, social, and institutional innovation processes for developing sustainability solutions (136). Interacting dynamics in urban areas have the potential for benefitting both urban populations and urban sustainability goals. Recent literature suggests that urban agglomerations—at least on the level of population—are part of the solution. The key is the arrangement of the ever larger populations of urban agglomeration into locations, forms, and functions that promote sustainability. The next section showcases examples from the scientific literature in urban land-use planning of how this can be achieved.

4.2. Urban Land-Use Planning

Although planning institutions have shown limited success in shaping urbanization, there are new opportunities for them to direct urbanization toward more sustainable forms, rates, and scales. Recent urban initiatives responding to climate change have led to collaborations among local authorities, planning institutions, the scientific community, and local stakeholders from both the private and public sectors (137). There is an increased awareness of the role that cities can play to mitigate climate change. Disciplinary studies have generated a wealth of knowledge about urban areas (e.g., economics, sociology, geography, climate studies, hydrology, and engineering). However, the lack of integration between urban planning and sustainability concepts has been recognized for nearly two decades (138). Bridging the gap between the science and practice of planning can help planning institutions better respond to the challenges of urbanization in the twenty-first century.

Recently, the planning community has proposed strategies to change traditional land-use planning to incorporate elements of climate change mitigation, adaptation, and sustainability. Tracing the history of environmental

planning in the United States, Daniels (139) suggests that the current era, with its focus on sustainability and the global environment, will engender a new phase of planning that will go beyond urban parks and managed growth to encompass a more systemic view of ecosystem well-being. Global change scientists are also recognizing importance of local land-use planning in achieving global environmental goals. In their review of atmospheric pollution in nine megacities around the world, Molina & Molina (140) conclude that "Good urban planning is needed to improve megacity air quality by encouraging people to live closer to where they work, developing cost-effective and convenient mass transit networks, creating economic activities outside of megacities to reduce migration incentives, and strategically locating industries."

Urban areas contribute to climate change, and climate change is also a major threat for global urban areas. A recent study puts global sea-level rise of 0.8 meters by 2100 "very likely," with a range between 0.8 and 2 meters (141). A rise of 0.8 meters in sea level would be catastrophic for many urban regions, not to mention the global economy. Urban responses to climate change have grown rapidly during the past decade in several parts of the world. Many of those responses have focused on mitigating the emission of greenhouse gases. The Alliance for Climate Protection in the United States includes more than 800 cities that have pledged to reduce greenhouse gas emissions. The Canadian Federation of Municipalities lists 150 members as part of its national campaign. Urban areas in Latin America, Europe, Asia, and Australia have initiated similar climate action plans (142).

In contrast, fewer urban areas have begun to consider adaptation as part of their responses to climate change (e.g., London, New York, Chicago, Toronto, Seattle, Denver, Manchester, King County in Washington State, Cartagena, Mexico City, Rotterdam, Durban, Cape Town) (142). Although climate change presents significant challenges for cities, it is also an opportunity to raise political support and resources, achieve stakeholder participation in urban governance, and to update and improve the knowledge and practice of urban development. Constructing multidimensional perspectives of urban areas and climate change through the collaboration among scientists, local planners, decision makers, and stakeholders can provide a solid basis to improve urban responses to climate change and, at the same time, affect the scale, rate, and form of urbanization.

Furthermore, there are clear synergies among mitigation, adaptation, and urban development strategies. However, the focus on climate change impacts obscures opportunities for reducing vulnerability in urban areas. Isolated discourses on adaptation and mitigation are unlikely to succeed and threaten to be insignificant if larger development issues are not taken into account (143). To be effective, capacity building for adaptation and development needs to squarely address the structural inequalities that create and sustain poverty, constrain access to resources, and threaten long-term sustainability (144). Despite the fact that social change is a central element of development, there is perhaps little attention to livelihoods in the efforts to connect vulnerability, mitigation, adaptation, and development. Rethinking frameworks for development to better understand the complexity of global problems (socioeconomic and biophysical) and their dynamic interaction in temporal and geographic scales with the local level is an area where further research is needed (142).

A point of clarification is in order in this discussion. Mainstreaming adaptation and mitigation strategies in urban policies can be achieved through formal mechanisms often found in urban planning (building codes, land-use permits) and through economic incentives common in the formal regulation of the built environment in many urban areas of high-income and middle-income countries. However, it would be unwise to neglect informal urban growth in many low-income and middle-income countries. Those communities have some of the most pressing needs in terms of their vulnerability to and ability to adapt to climate change.

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Creating adaptation and mitigation strategies in these communities requires different methods because urban growth takes place outside the formal framework of urban planning. Information on future scenarios of climate extremes and adaptation strategies is also a useful planning tool for community-based organizations and NGOs engaged in improving poor urban communities as well as for the local governments that interact with them.

4.3. Can Rapid Urbanization Save the Environment?

In light of the urbanization processes underway, can the global environment afford not to urbanize? Put another way, what would be the differential impact of 3 to 5 billion new urban dwellers if they lived in different types of urban settlements? To answer this question, we ran a simple hypothetical scenario using UN estimates of the size of the new urban population between 2010 and 2050. We calculated greenhouse gas emissions from the growth of urban population hypothetically distributed across three types of cities: high density, moderate density, and low density.

We used four total population scenarios with variants in fertility derived from the UN World Population Prospects (145) and the projected urbanization levels across regions in 2050 to derive four possible urban futures. The low-, medium-, and high-fertility scenarios assume 1.35, 1.85, and 2.35 children per woman, respectively. The constant fertility scenario assumes that, for each country, fertility remains constant at the level estimated for 2005–2010. That is, if the fertility rate for a country is 2.1 children per woman during 2005–2010, it remains at 2.1 through 2050. By way of comparison, the world total fertility rate for 2005–2010 is estimated at 2.56 children per woman. The four population scenarios only assume differences in fertility rates. Other scenarios exist that make assumptions about mortality and migration, but they are not included in our analysis. Under these four fertility scenarios, the growth in global urban population between 2010 and 2050 ranges between 1.9 billion and 4.7 billion people.

We used these estimates of projected urban population growth to develop scenarios of greenhouse gas emissions. We used Washington, DC, Toronto, Canada, and Seoul, South Korea, as our representative low-, moderate-, and high-density cities, with per capita greenhouse gas emissions circa 2000 of 19.7, 8.2, and 3.8 tonnes, respectively. Using these reported emissions per capita, we calculated global distribution of total emissions assuming the new urban populations of each region lived in one of the representative cities (122).

The results of this exercise are shown in **Figure 5** (see color insert). The rows show different population scenarios, and the bars show the emissions associated with the growth in urban population living in different types of urban settlements; low-, medium-, and high-density cities are shown in red, orange, and pink, respectively. Not surprisingly, if the growth in global urban populations results in low-density cities, this will result in the highest greenhouse gas emissions. The high-fertility population growth scenario coupled with low-density urban living leads to world greenhouse gas emissions of 786 billion tonnes in 2050. Caution should be given to the case of Europe where the constant- and low-fertility scenarios produce a reduction in greenhouse gas emissions owing to a decline in total and urban population. Although the European case should be investigated further, especially because these estimates do not capture migration processes, the results clearly show that Asia is a major region of concern for the potential effects of future urban populations.

The critical point is that the scenarios show that savings in emissions from different types of urban development and associated lifestyles are tremendous, irrespective of the fertility rate. Even with the low-fertility scenario, if the growth in urban population over the next 40 years leads to low-density cities like Washington, DC, this would result in an increase of 380 billion tonnes of emissions in 2050. These calculations do not include cumulative

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emissions up to 2050, only emissions in the year 2050. In contrast, if the growth in urban populations is housed in high-density cities like Seoul, the high-fertility scenario generates only a total of 152 billion tonnes in 2050, less than half of the total emissions under a low-fertility, low-density scenario. The constant fertility scenario coupled with low urban densities produces the highest emissions (937 tonnes), but this is the least likely population growth scenario.

Although this exercise is only illustrative, it is an important first step to asking the question of "How can we urbanize with less impact on the global environment?" This simple exercise shows the magnitude of the gains—and costs—associated with different types of urbanization scenarios. The analysis does not factor in the environmental and social costs of building and living densely. For example, how much land do we save for nature, agricultural production, forests, and habitat when global populations live in dense cities? Similarly, the analysis does not include all the environmental and social costs of building and living densely and the consumption effects associated with urbanization. The recent global study on deforestation suggests that, although urbanization may save land for nature, urbanization can also result in an increase in incomes, which then spurs demand for agricultural and forests products, thereby driving deforestation elsewhere. There is much work in this area across disparate but complementary fields. The challenge moving forward is to develop multidimensional approaches to understanding the relationship between urbanization and the environment that do not depend on a single solution.

5. CONCLUSIONS AND FUTURE DIRECTIONS

Urbanization is occurring faster and at greater magnitudes in geographic locations that are at lower stages of economic development and face rapid demographic changes. This, in turn, is accelerating global environmental change. Urban systems will continue to disproportionately affect ecologically fragile areas and contribute to the loss of agricultural land compared to other systems. Urban growth in coastal and arid ecosystems will be particularly sensitive to the effects of climate change. We project that sprawling urban development will continue to be the dominant growth pattern, but factors such as energy price shocks or economic downturns could reverse or halt this trend. Urbanization hot spots lack balance in their growth, such as adequate durable housing, access to improved water, key resources, and sanitation, and are also overcrowded, with high levels of unemployment and social exclusion. Institutional settings in such hot spots are weak, lack accountability, and face rampant corruption. All the above factors, operating in concert with climate change impacts, create "stress bundles" that increase vulnerability to dangerous climate change (146).

Agglomeration across scales continues to be a dominant global trend, presenting—on a first level—benefits for urban sustainability. There are primarily two advantages from urban population increase: (*a*) increasing returns from innovation and productivity; and (*b*) economies of scale in energy use, carbon emissions, and infrastructure provision. Still, population is not the only or most important factor shaping the relationship of urban areas with the environment. This article highlights the importance of other factors, such as urban form and function, institutions, and governance structure. The relationships between urbanization and the environment, and thus opportunities for sustainability, are largely determined by the spatiality of urban areas. Higher densities of jobs and people can lead to more walking, less driving, less energy, and less carbon emissions. However, such outcomes require investments in public infrastructure that encourage transit development, as well as zoning that allows a mix of land uses (4). Infrastructure planning is also needed at a scale beyond that of an individual city. Rather, we need urban development strategies that take a "system of cities" perspective and that formulate polices at a regional or national scale.

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In short, agglomeration cannot operate alone; it is just one piece of the puzzle of urban sustainability. Integrated urban land-use planning has potential for offering significant solutions. Urban form and function interventions along with good urban governance can further assist in enhancing the process of sustainable development, but agglomeration plays a big role in putting communities on the right path. For the urban settlements that will be home to the 3 to 5 billion new urban dwellers over the coming decades, the challenge ahead is to leverage urban development efforts, including human and financial resources, to create solutions that simultaneously mitigate and adapt to climate change.

The challenge for humanity is how to change the current scale, form, and rate of urbanization to build opportunities for sustainability in both developed and developing countries. We highlight in our discussion the need of multidimensional and multiscale approaches to better understand the complexity of urbanization in the twenty-first century. This is the best way to integrate current and future effort to respond (by mitigation and adaptation) to climate change in urban areas within a broader framework of urban sustainability that helps build coherence and benefits in the short- and long-term for societies.

We started this article by stating that we are entering a new era, the Astycene. Urban areas have been a prominent feature of humanity throughout most of history. Yet, we have a hard time recognizing how urban areas illustrate the dramatic transformations in societies during the last century. The conflicts and imbalances among countries and within countries create severe obstacles to building efficient responses to new challenges like climate change. The transition to an urban century illustrates the need for a new way of thinking and understanding the increasing complexities of our societies. Making sense of the new urban realities can contribute to a more comprehensive understanding of our common future. Integrating responses to climate change—by mitigation and adaptation—with strategies for urban development can help us transition to sustainability but will require multidimensional and multiscale approaches to the study and management of urban areas.

SUMMARY POINTS

1. Contemporary urbanization fundamentally differs from historic patterns in its scale, rate, geographic reach, form, and function, and it is characterized by its many interconnected dimensions.
2. Urban areas are not just about the physical and built environment, but also about institutions, governance, and social processes. We need to view urban processes as part of a comprehensive and complex system.
3. The physical structure and character of contemporary urbanization throughout the world is increasingly similar to those of North American cities, but at larger scales and occurring with greater rapidity. These trends are most evident in developing country cities and, if they continue over the next 40 years, will have significant implications for local and global sustainability.
4. In addition to demographic and economic forces, agglomeration, changes in governance and institutions, and international capital are interacting to amplify their individual impacts on urbanization processes and are accelerating changes in the physical structure and character of urban areas.
5. Contemporary urbanization has the potential to help the transition to sustainability solutions because of gains from scale in innovation, productivity, and efficiency.

6. The way the scale, form, and rate of urbanization takes place makes a significant impact on sustainability. However, we need to develop a multidimensional and multidisciplinary perspective.
7. Historically, urbanization has been viewed as an environmental ill, but rapid urbanization can actually accelerate a transition to sustainability owing to forces of agglomeration, increased innovation, and increased wealth. However, urban growth needs good governance structures in order to achieve this.

FUTURE ISSUES

1. How can perspectives on and agendas for sustainability explicitly incorporate future urbanization?
2. What are the most significant opportunities to develop triple-win solutions and strategies for climate change mitigation and adaptation and urban development?
3. How will the confluence of contemporary urbanization and global environmental change exacerbate or accelerate issues of equity?
4. We have a very limited understanding of the dynamic interactions in urban areas. What are the complex interactions between institutions, governance, energy choices, and built space? What are the social outcomes of the built environment?
5. What forms of urban growth have less environmental impact? And what are the governance and institutional structures necessary to achieve them?

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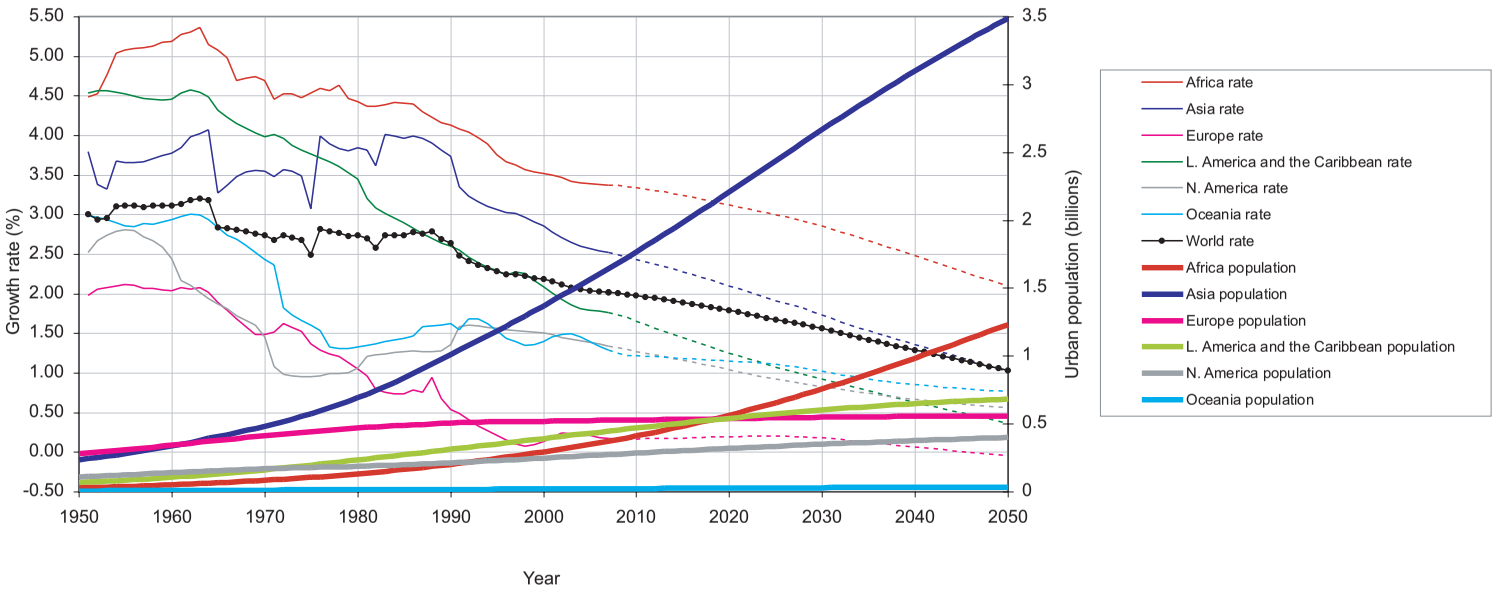

Figure 1

Annual urban population growth and growth rate by world region. Thin lines denote rates of change; thick lines represent magnitudes. Dashed lines represent UN projections. This figure was produced from data in Reference 16.

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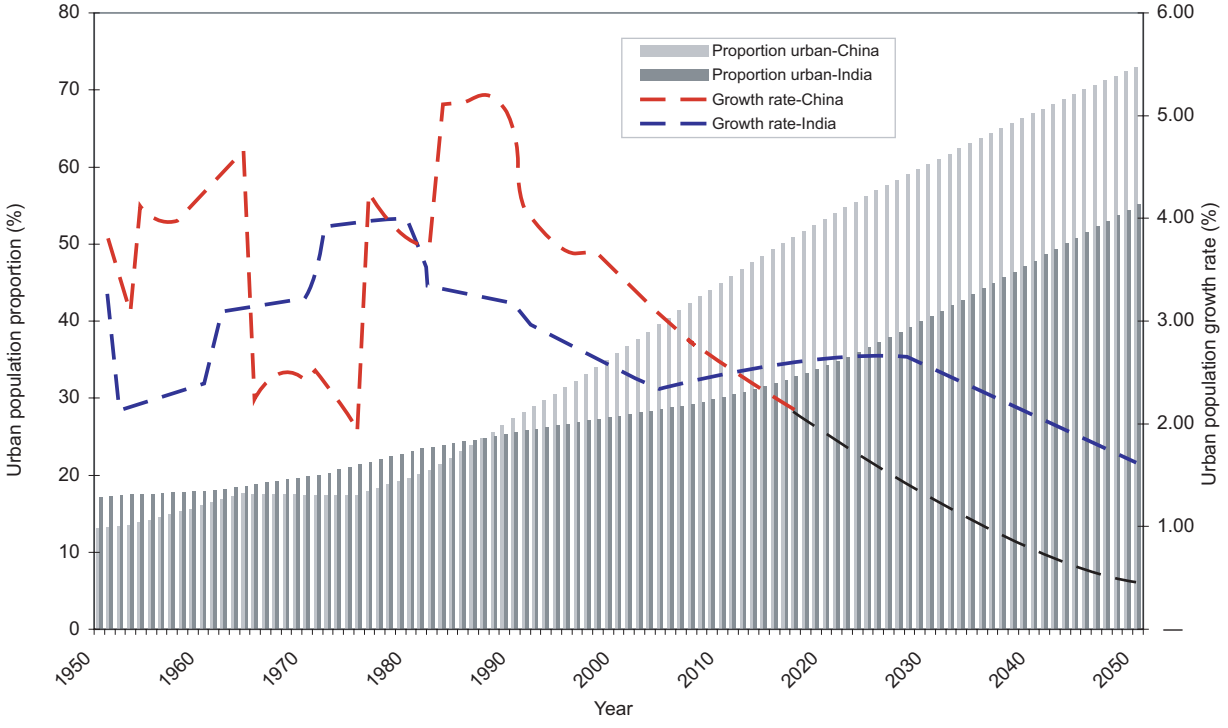

Figure 2

Annual urban population growth rates and proportion urban population of China and India (16).

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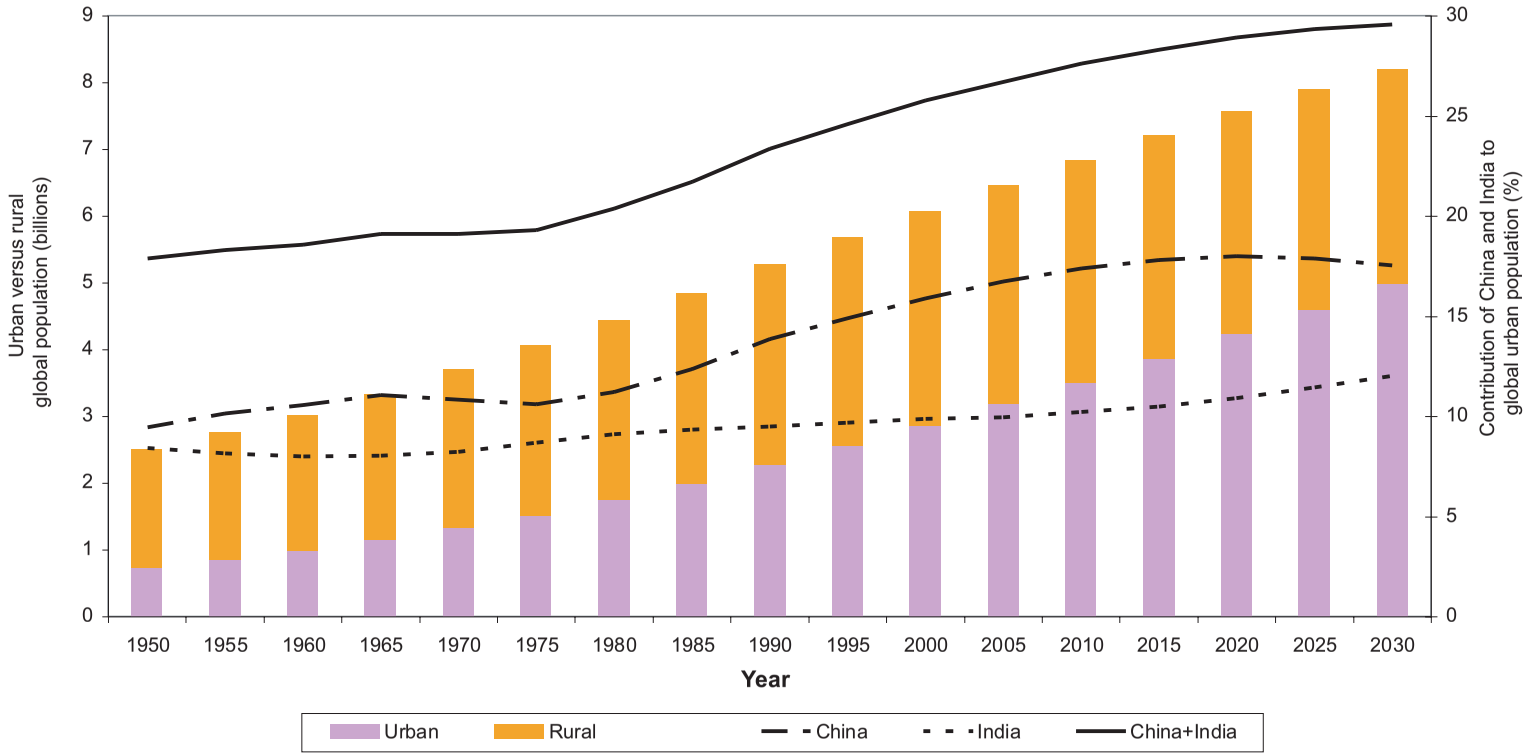

Figure 4

Urban population of China and India as percentage of global urban population (145).

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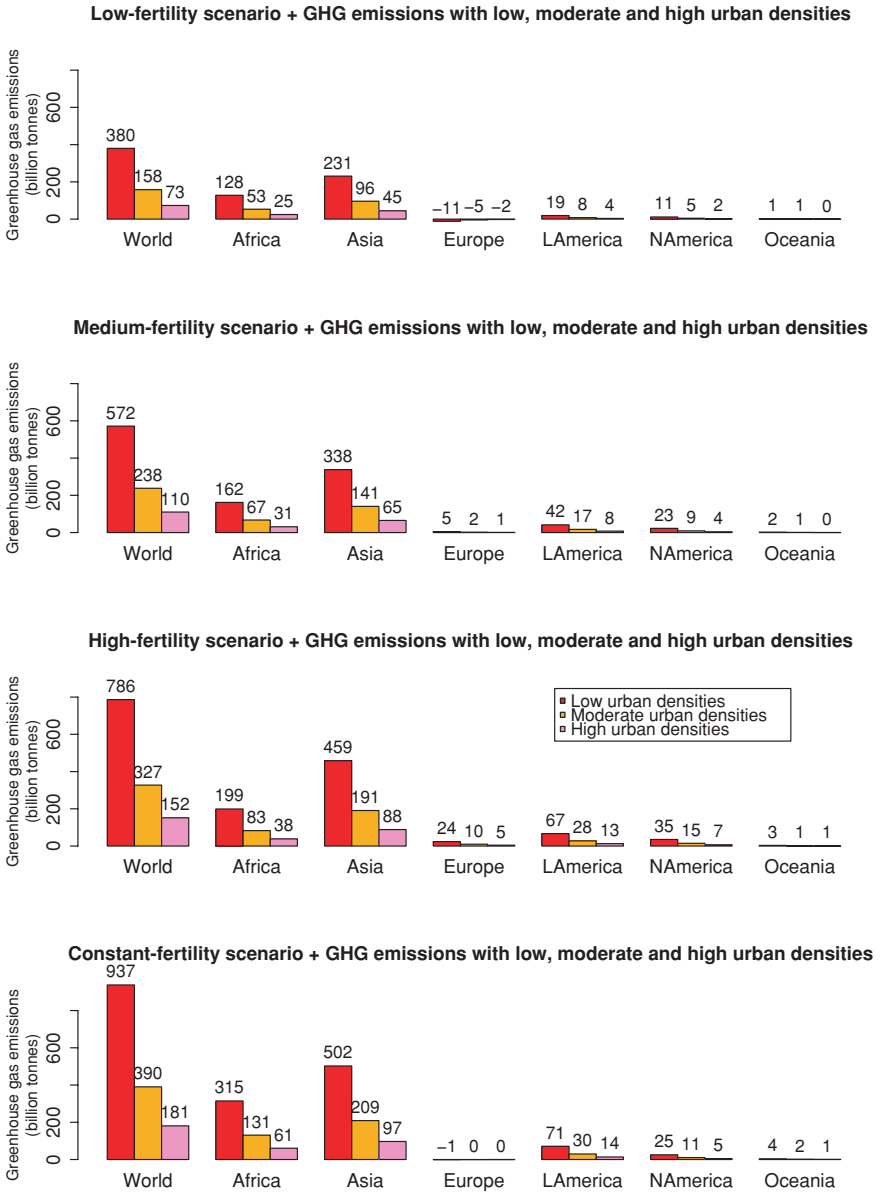

Figure 5

Estimates of greenhouse gas emissions based on types of urban settlements and expected urban population growth. The rows show different urban population (due to fertility) scenarios, and the bars show the emissions associated with the growth in urban population living in different types of urban settlements; low-, medium-, and high-density cities are shown in red, orange, and pink, respectively. Scenarios for urban population growth are from Reference 145. Estimates of greenhouse gas emissions per capita for different types of cities are from Reference 122. LAmerica, Latin America; NAmerica, North America.

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