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Urban Form, Greenhouse Gas Emissions and Climate Vulnerability

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Introduction

This chapter presents an analytical review of the interaction among urban density, climate change and sea level rise. It focuses on two main themes: (1) the interaction between urban density and the generation of greenhouse gases and how this affects mitigation strategies; and (2) the consequences of climate change on urban settlements of varying population densities and how this affects adaptation strategies. Throughout, there is a recognition that changing population densities—and broader demographic issues—in urban centres can both affect and be affected by global environmental change.

First, as is already well known, climate change is caused by the emission of greenhouse gases, primarily from the combustion of fossil fuels. Greenhouse-gas-emitting activities are distributed in a spatially uneven manner. On the global scale, the 20 per cent of the world's population living in high-income countries account for 46.4 per cent of global greenhouse gas emissions, while the 80 per cent of the world's population living in low- and middle-income countries account for the remaining 53.6 per cent. The United States and Canada alone account for 19.4 per cent of global greenhouse gas emissions, while all of South Asia accounts for 13.1 per cent and all of Africa just 7.8 per cent (Rogner et al., 2007). This chapter therefore examines the implications of different urban densities for the emission of greenhouse gases (particularly, although not exclusively, in high-income countries) and the implications of this for global climate change. The relationships among the form, density, economy and society within cities are explored in order to assess whether particular spatial patterns can have a positive or negative effect on the emission of greenhouse gases and, consequently, on climate change.

Secondly, it is increasingly accepted that the effects of climate change will also be distributed unevenly. High urban densities can both contribute to and reduce the vulnerability of human populations. If populations are concentrated in vulnerable locations, without proper infrastructure or institutional frameworks, density can increase risk. However, if effective means can be found for supporting dense populations in safe locations with suitable infrastructural and institutional frameworks, a viable alternative to living on marginal and unsafe sites can be provided, particularly for the urban poor. Other aspects of demography, such as the gender and age composition of a population, also affect vulnerability. This chapter therefore examines patterns of urban density and vulnerability (particularly, although not exclusively, in low- and middle-income countries) and the inter-relationships between the two. Specifically, it examines case studies of high-population densities that increase exposure to the effects of climate change and vulnerability and case studies of high-population densities that can be seen to reduce risk. If well-managed, the increasing concentration of population in urban centres can result in a reduction in vulnerability to the direct and indirect impacts of climate change; if poorly managed, it can mean increasing levels of risk for large sections of the urban population.

These processes do not occur in isolation and cannot be separated from broader demographic, economic and social transformations. This chapter therefore approaches the interaction between climate change and urban density in a holistic manner that can identify appropriate, context-specific and policy-relevant recommendations. The analysis provided will help to strengthen capacity at the national and local levels to understand and deal effectively with urbanization in the face of the challenges posed by climate change.

Approaching Urban Density

Views of urban density have tended to be starkly polarized. Low-density cities are seen either to enable individual freedom and spacious living or to be a profligate and wasteful use of space and resources. Dense urban populations are considered to be indicative of claustrophobic squalor, poverty and deprivation, or of diversity and community. On the one hand, Ebenezer Howard's protests against urban overcrowding are still invoked: Howard argued that "[i]t is well nigh universally agreed by men of all parties . . . that it is deeply to be deplored that the people should continue to stream into the already overcrowded cities" (Howard, 1996, p. 346). On the other hand, Jane Jacobs' (1996) passionate defense of urban life in *The Death and Life of Great American Cities* is still taken as a mantra, particularly for those in the intellectual movement of 'new urbanism' who are opposed to the growth patterns of suburban sprawl and restrictive residential enclaves. For this latter group, low urban densities—frequently associated with the process of suburbanization—are often characterized as urban sprawl.

Both the definition and the effects of urban sprawl are widely debated. Frenkel and Ashkenazi (2008) identify five different systems for measuring sprawl—growth rates, density, spatial geometry, accessibility and aesthetic measures—with settlement patterns identified as sprawl when they meet one measure but not necessarily any of the others. Urban sprawl is often associated with a variety of social problems including "social isolation and obesity; asthma and global warming; flooding and erosion; the demise of small farms; extinction of wildlife and the unbalancing of nature" (Gottdiener and Budd, 2005, p. 148). In contrast, some planners see sprawl as inevitable or harmless, arguing that it maximizes the overall welfare of society as an outcome of free-market decision-making, provides easy access to open space and results in lower crime rates (Frenkel and Ashkenazi, 2008). But in many respects, the use of the term 'sprawl' has negative connotations and may serve to close spaces for discussion and negotiation. There is a clear need to move beyond these kinds of polarized positions and—as proposed later in this chapter—to accept a more nuanced view of the advantages and disadvantages of particular urban forms and levels of density.

In low- and middle-income countries, the related process of peri-urbanization is increasing. In the peri-urban interface, the boundaries between the 'urban' and the 'rural' are continually being renegotiated and, rather than being clearly defined, are characterized by transition zones. These interfaces are affected by some of the most serious problems of urbanization, including intense pressures on resources, slum formation, lack of adequate services such as water and sanitation, poor planning and degradation of farmland. They are of particular significance in low- and middle-income countries, where planning regulations may be weak or weakly enforced and therefore result in areas with complex patterns of land tenure and land use (McGregor et al., 2006; Tacoli, 2006). Although peri-urban areas provide a variety of activities and services for urban centres, they are generally beyond or between the legal and administrative boundaries of these cities, with the result that the process of urbanization can be unplanned and informal with frequent struggles over land use.

The relationship between urban population density and the environment in its broader sense is further complicated by the spatial displacement of environmental costs. Although it is often argued that denser urban settlements make more efficient use of land and other resources, at least some of this can be attributed to their 'ecological footprints' outside the spatial boundaries of the city (Wackernagel and Rees, 1995; Wackernagel et al., 2006). This displacement of environmental costs is particularly relevant to climate change when 'consumption-based' rather than 'production-based' measures of greenhouse gas generation are utilized. Many cities in North America and Europe are service-oriented rather than production-oriented, yet traditional mechanisms for identifying the source of greenhouse gas emissions allocates these to the location of production, rather than to the location of the consumption of the finished product (Bai, 2007).

At its simplest, urban density is measured by dividing a given population by a given area. The widely varying definitions of the spatial extent of urban areas lead to a great deal of difficulty in generating comparable statistics for different towns and cities. Dividing the population of a metropolitan area by the administrative areas contained within its official boundaries is a highly unreliable measure—particularly for comparisons—because the density will vary according to the definition of these boundaries (Angel et al., 2005). In addition, standard measures of density are calculated over an entire land area, without taking into account the levels of connectivity. For example, the gradual transformation of the urban form of Curitiba, Brazil, from a predominantly radial-circular form to a more linear pattern of development has reduced the city's overall density, yet it has facilitated the development of a more rapid and effective public transportation system and produced various other social and environmental benefits.

At the global level, however, there is strong evidence that urban densities have generally been declining over the past two centuries (UNFPA, 2007). Perhaps the most detailed and compelling assessment of this phenomenon is provided by a recent World Bank report (Angel et al., 2005). This report used a method of measuring the density of the *built-up* area (as defined through satellite imagery) rather than the *administrative* area of cities, and applied this to a total of 3,943 cities with populations greater than 100,000. These cities had a total population of 2.3 billion people: 1.7 billion in 'developing' countries and 0.6 billion in 'industrialized' countries. According to the report, the average density of cities in industrialized countries in 2000 was 2,835 people per km^2, declining from 3,545 people/km^2 in 1990, with an annual change of -2.2 per cent. In developing countries, the average urban population density in 2000 was 8,050 people/km^2, declining from 9,560 people/km^2 in 1990, with an annual change of -1.7 per cent. Alternatively, these figures can be expressed as the average built-up area per person: $125m^2$ in developing country cities and $355m^2$ in industrialized country cities.

Table 4.1: Average Density of Built-up Areas (persons per km^2)

	1990	2000
Less-developed Countries	9,560	8,050
Industrialized Countries	3,545	2,835
East Asia and the Pacific	15,380	9,350
Europe	5,270	4,345
Latin America and the Caribbean	6,955	6,785
Northern Africa	10,010	9,250
Other Developed Countries	2,790	2,300
South and Central Asia	17,980	13,720
South-East Asia	25,360	16,495
Sub-Saharan Africa	9,470	6,630
Western Asia	6,410	5,820
Low Income	15,340	11,850
Lower-middle Income	12,245	8,820
Upper-middle Income	6,370	5,930
High Income	3,565	2,855

Source: Adapted from Angel et al., 2005.

This trend of reduced urban densities is likely to continue into the future. It is estimated that the total population of cities in developing countries will double between 2000 and 2030, but their built-up areas will triple (from approximately 200,000 km^2 to approximately 600,000 km^2); in industrialized countries, the urban population will increase by approximately 20 per cent, while their built-up areas will increase 2.5 times (from approximately 200,000 km^2 to approximately

500,000 km^2). The agglomerated figures for industrialized and developing countries conceal a great deal of regional variation (see Table 4.1). In 2000, South-East Asian cities were almost four times as densely populated as European cities, and almost eight times as densely populated as those in 'Other Developed Countries' (including North America and Australasia). These figures can also be disaggregated by income levels: Cities in low income countries are more than four times as densely populated as cities in high-income countries.

In summary, the average density of built-up areas in all cities, in all regions and of all population sizes is decreasing. As has been shown, however, this is a highly uneven process. Larger cities tend to exhibit higher densities than smaller cities (McGranahan et al., 2007), and these figures do not capture the variations in density that exist within cities. Although the density for any given urban area as a whole may be declining, there are still likely to be pockets of extremely high density, and these are likely to be associated with low-income residential areas. The following sections of this chapter assess the relationship between these patterns of urban density and the different aspects of climate change in a greater level of detail.

Urban Density and Greenhouse Gas Emissions

Urban form and urban spatial organization can have a wide variety of implications for a city's greenhouse gas emissions. The high concentrations of people and economic activities in urban areas can lead to 'economies' of scale, proximity and agglomeration that can have a positive impact on energy use and associated emissions, and the proximity of homes and businesses can encourage walking, cycling and the use of mass transport in place of private motor vehicles (Satterthwaite, 1999). Some researchers suggest that each doubling of average neighbourhood density is associated with a 20-40 per cent decrease in per-household vehicle use and a corresponding decline in emissions (Gottdiener and Budd, 2005, p. 153). Newman and Kenworthy (1989), for example, suggested that gasoline use per capita declines with urban density (although they acknowledged that the correlation weakens once GDP per capita is taken into account), and Brown and Southworth (2008, p. 653) argue that "by the middle of the century the combination of green buildings and smart growth could deliver the deeper reductions that many believe are needed to mitigate climate change".

Yet cities have often been blamed for generating most of the world's greenhouse gas emissions and for contributing disproportionately to global climate change. Referring specifically to climate change, the Executive Director of the United Nations Centre for Human Settlements (UN-HABITAT) has stated that cities are "responsible for 75 percent of global energy consumption and 80 percent of greenhouse gas emissions"; while the Clinton Foundation suggests that cities contribute "approximately 75 percent of all heat-trapping greenhouse gas emissions to our atmosphere, while only comprising 2 percent of land mass" (For references to these and similar quotations, and a detailed critique, see Satterthwaite, 2008). At the same time, detailed analyses of urban greenhouse gas emissions for individual cities suggest that, per capita, urban residents tend to generate a substantially smaller volume of carbon emissions than residents elsewhere in the same country (Dodman, 2009). Indeed, per capita emissions in New York City are only 29.7 per cent of those in the United States as a whole (PlaNYC, 2007); those in London are just over half of the British average (Mayor of London, 2007); those in Rio de Janeiro are only 28.0 per cent of those of Brazil as a whole (Dubeux and La Rovere, 2007); and those in Barcelona are only 33.9 per cent of those of Spain as a whole (Baldasano et al., 1999). These relatively low levels of emissions are influenced by a variety of factors—including the density of buildings, the average dwelling unit size and the extent of public transportation—several of which are linked directly to patterns of urban density.

Dense urban settlements can therefore be seen to enable lifestyles that reduce per capita greenhouse gas emissions through the concentration of services that lessens the need to travel long distances, the (generally) better provision of public transportation networks and the constraints on the size of residential dwellings imposed by the scarcity and high cost of land. Yet conscious strategies to increase urban density may or may not have a positive effect on greenhouse gas emissions and other environmental impacts. Many of the world's most densely populated cities in South, Central and South-East Asia suffer severely from overcrowding, and reducing urban density would meet a great many broader social, environmental and developmental needs. High urban densities can cause localized climatic effects such as increased local temperatures (Coutts et al., 2007). In addition, a variety of vulnerabilities to climate change are exacerbated by density: Coastal location, exposure to the urban heat-island effect, high levels of outdoor and indoor air pollution and poor sanitation are associated with areas of high population density in less-developed-country cities (Campbell-Lendrum and Corvalán, 2007). However, there are clear opportunities for simultaneously improving health and cutting GHG emissions through policies related to transport systems, urban planning, building regulations and household energy supply.

Conversely, some of the apparent climate change mitigation benefits of high urban densities in industrialized countries may be a consequence of the spatial displacement of greenhouse-gas-generating activities to other locations within the same country or internationally. Reducing greenhouse gas emissions—or addressing climate change mitigation—can only be meaningfully achieved through a process of reducing both direct and indirect emissions.

Policy implications: Density and 'climate friendly cities'

Although the relationship between urban density and greenhouse gas emissions is complex, there are certain lessons that can be identified as relevant for urban policy. These do not amount to wholesale recommendations in favour of densification, but rather look at strategically assessing population distribution in a manner that contributes to broader goals of climate change mitigation. Encouraging densification at an aggregate scale—within administrative boundaries, for example—risks neglecting the important environmental and social roles played by gardens and open spaces. It is also worth considering the different housing needs for individuals at different stages of life and reconsidering the notion of 'housing for life' that has been prevalent in many national housing policies (Minerva LSE, 2004). In this regard, dense settlement patterns may meet the needs of certain groups within society, but not others.

In general, however, density does provide the potential for access to and use of public transportation—when designed to meet the needs of users. A report by Minerva LSE (2004) shows a "positive link between higher-density areas and levels of public-transport access across London, which is reflected in the decisions that people make about how to get to work" (p. 4). It further concludes that "on balance, people will use public transport where it is available, especially in high density, centrally located areas". This case study of London also shows how high density areas can accommodate both deprived and affluent communities, in which there is a shared willingness to live in economically successful parts of the British capital at high densities. People appear to 'trade off' more space in their homes for other qualities, such as personal and property safety, the upkeep of the area and proximity to shops and amenities.

Access to public transportation need not imply high density, as shown by the concepts of 'transit-oriented development' and 'transit villages' pioneered in California (California Department of Transportation, 2002). They are characterized by moderate- to high-density housing within easy walking distance of major transit stops. Similar processes can be facilitated in low- and middle-income nations through the development of bus rapid transit systems. These are most efficient in servicing densely populated linear developments, which contain a large number of urban residents who live within walking distances of the main trunk routes. The first comprehensive example of this type of development began in Curitiba, Brazil, in the mid-1970s; Curitiba now has an integrated public transport system focused on five main 'axes' that is used by two thirds of the city's population (Rabinovitch, 1992). More recently, the TransMilenio public transportation system was developed in Bogotá, Colombia (Héron, 2006). It is also based on a trunk-route system with feeder services, which does not necessarily imply consistently high urban densities. However, it has been successful at meeting the needs of the 80 per cent of the city's population who are dependent on public transportation, including the 53 per cent who are defined as living in poverty.

These examples from North and South America show that innovative thinking in relation to the planning of transportation infrastructure can meet both environmental and social needs. Localized areas of relatively high densities are required to generate greater efficiencies in the use of public transportation, but this can be consistent with meeting a variety of other demands from urban residents. Of course, the precise form that these transportation networks—and other urban networks (for supplying electricity, water, etc.)—should take requires detailed local study. Overall, however, density is one of several factors that affect energy use—and by extension greenhouse gas emissions—in towns and cities. Addressing these issues requires ongoing analysis of *urban processes,* rather than simply taking a snapshot of *urban form* at a particular moment in time.

Urban Density and Climate Change Vulnerability

A second major interrelationship between population density and climate change is in patterns of density and vulnerability. Densely populated urban areas—especially in low- and middle-income countries—are particularly vulnerable to the effects of climate change. Where there are dense concentrations of households and economic activities, the effects of climate change can impinge on large numbers of people and have a major impact on urban economies—even if they affect only relatively small land areas. However, if appropriate infrastructure is developed in areas that are less likely to be influenced by climate change, an opportunity to build large-scale resilience could be provided in a relatively cost-effective manner.

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report of 2007 unequivocally states that the earth's climate system has been undergoing warming over the last 50 years. Projections of future global average surface warming (for the decade 2090-2099 relative to 1980-1999) range from 1.1° to 6.4°C, whilst sea level rise is predicted at 18 to 59cm (IPCC, 2007). Mean temperatures are likely to increase, mean precipitation will fluctuate and mean sea level will rise; extreme rainfall events and tropical cyclones are likely to be more frequent and intense, leading to more frequent flooding (both riverine and storm surge). Climate change is likely to exacerbate many of the risks faced by low-income urban residents: The IPCC states that "poor communities can be especially vulnerable, in particular those concentrated in relatively high-risk areas" (Wilbanks et al., 2007, p. 359). Urban areas in low- and middle-income nations already house a large percentage of the people and economic activities most at risk from climate change, including extreme weather events and sea level rise, and this proportion is increasing.

The main impacts of climate change on urban areas, at least in the next few decades, are likely to be increased levels of risk from existing hazards. For poorer groups, these will include direct impacts such as more frequent and more hazardous floods; less direct impacts such as reduced availability of freshwater for many cities that may limit the supplies available to poorer groups; and indirect impacts such as the effects of climate-change-related weather events that increase food prices or damage poorer households' asset bases (Dodman and Satterthwaite, 2008).

Urban population density, climate change and disasters

The dense concentration of urban populations can increase susceptibility to the disasters that are likely to become more frequent and more intense as a result of climate change. Economies, livelihoods, physical infrastructure and social structures are all important components of urban systems and are vulnerable to disasters and climate risk in different ways. However, far more is known about the environment of risk (the factors leading to vulnerability) than of the risk impact (the number of deaths and serious injuries and the damage to property and livelihoods when disasters occur). But the (limited) available evidence suggests that the number of serious injuries and deaths from disasters in urban areas has been growing in most low- and middle-income nations (UN-HABITAT, 2007).

Dense urban populations in high-income nations take for granted a web of institutions, infrastructure, services and regulations that protect them from disasters—including extreme weather, floods, fires and technological accidents. Many of the measures to protect against these involve services that also supply everyday needs, including health care services integrated with emergency services and sewer and drainage systems that meet daily requirements but that can also cope with storms. Almost everyone lives and works in buildings that meet health and safety regulations and that are served by infrastructure designed to cope with extreme weather. The police, armed services, health services and fire services, if or when needed, provide early warning systems and ensure rapid emergency responses. Consequently, extreme weather events rarely cause a large loss of life or serious injury. Although occasionally such events cause serious property damage, the economic cost is reduced for most property owners by property and possessions insurance. In contrast, only a very small proportion of urban centres in low- and middle-income nations have a comparable web of institutions, infrastructure, services and regulations, although there are very large variations among such centres in the extent of provision and coverage. The proportion of the population in cities that lives in legal homes built according to appropriate building regulations varies widely, as does the proportion of the population living in homes adequately served by sanitation, wastewater removal and storm drains (Hardoy et al., 2001).

However, the fact that disasters often have a disproportionate impact on areas of high population density does not necessarily mean that density itself is to blame for increasing vulnerability. Rather, it is the fact that inadequate institutions and lack of infrastructure are often concentrated in areas where there are also high population densities of low-income urban residents. In and of itself, reducing density is not a solution to reducing vulnerability to climate-change-related disasters: after all, many poor, dispersed, rural populations also suffer horrendously from climatic and other disasters. Instead, reducing vulnerability to climate change in high density urban settlements requires the provision of adequate infrastructure and services. Given the necessary political will and financial resources, this can be achieved relatively economically in dense settlements, as any improvements made can benefit a large number of people.

Low-income groups often have no choice but to settle on already densely populated marginal land, as no other suitable land is available. Because of this, one particularly important response to urban climate change vulnerability is to make adequate and appropriately located land available to low-income urban groups. This approach has been implemented successfully in the city of Manizales in Colombia, which has managed to avoid rapidly growing low-income populations settling on dangerous sites (Velásquez, 2005). The population of Manizales was growing rapidly, with high levels of spontaneous settlement in areas at risk from floods and landslides. Local authorities, universities, non-governmental organizations and communities worked together to develop programmes aimed not only at reducing risk, but also at improving the living standards of the poor. Households were moved off the most dangerous sites and re-housed nearby. Most of the former housing sites were converted into eco-parks with strong environmental education components. A similar approach was implemented in the city of Ilo in Peru (Díaz Palacios and Miranda, 2005). Although the city's population increased fivefold between 1960 and 2000, there have been no land invasions or occupations of risk-prone areas by poor groups, because local authorities have implemented programmes (such as the acquisition of an urban-expansion area) to accommodate this growth and to support the poor in their efforts to achieve decent housing. At the same time, improvements were made in water supply, sanitation, electricity provision, waste collection and the provision of public space. Similar interventions—with a strong focus on providing safe and accessible land for high density housing for the urban poor—are required to reduce climate change vulnerability in densely populated towns and cities around the world.

Urban population density, climate change and health

Climate change is also likely to affect human health in urban centres. This is of particular concern in the Least Developed Countries, which already experience a high burden of climate-sensitive diseases. Many of these health risks are exacerbated in densely populated urban areas. In addition to the direct mortality effects of more frequent and extreme weather events, climate change will also affect human health through changes in vector-borne disease transmission, increased malnutrition due to declining food yields and increases in diarrhoeal diseases from changes in water quality and water availability. This is a highly inequitable situation, as those who are at greatest risk are also those who have contributed the least to greenhouse gas emissions.

Climate change is likely to result in more frequent and intense heat waves. In cities, these are exacerbated by the urban heat-island effect as a result of lower evaporative cooling and increased heat storage in roads and buildings, which can make temperatures 5-11°C warmer than in surrounding areas. Heat waves can have dramatic impacts on human health: The European heat wave of August 2003 caused excess mortality of over 35,000 people (Campbell-Lendrum and Corvalán, 2007). Heat waves can result in significant deleterious economic effects due to decreased productivity and the additional cost of climate-control within buildings, as well as generating 'knock-on' environmental effects, such as air pollution and increased greenhouse gas emissions if these cooling needs are met with electricity generated from fossil fuels (Satterthwaite et al., 2007). There is also some evidence that the combined effects of heat stress and air pollution may be greater than the apparent additive effect of these two stresses (Patz and Balbus, 2003). The effects of heat stress are distributed unevenly within urban populations, with elderly persons being especially vulnerable.

As noted, densely populated urban areas may become increasingly vulnerable to vector-borne diseases due to climate change, as shifting climate patterns extend the range of certain vectors. In general, the higher rates of person-to-person contact in dense urban settlements can help to spread infectious diseases more quickly. Rapid unplanned urbanization can produce breeding sites for mosquitoes, high human population densities can provide a large pool of susceptible individuals, and higher temperatures can cause an increase in high absolute humidity that can also extend the species' range (Campbell-Lendrum and Corvalán, 2007). Diseases spread in this way include dengue fever, malaria and filariasis. However, although climate change is likely to result in the expansion of malaria-carrying mosquitoes to some new locations, it is likely to cause the contraction of this range in other areas (Confalonieri et al., 2007).

But the effects of climate change on human health in densely populated urban settlements are not insurmountable. Indeed, although the current burden of climate-sensitive disease is highest among the urban poor, it is not the rapid development, size and density of cities that are the main determinants of vulnerability, but rather the increased populations living in hazard zones, flood plains, coastal hazard risk zones and unstable hillsides vulnerable to landslides. In the next few decades, good environmental and public health services should be able to cope with any increase in climate-change-related health risks—whether caused by heat waves or reduced fresh-water availability or greater risks from communicable diseases. However, providing these services requires firm commitments to build the necessary infrastructure on the part of municipal and national governments, as well as on the mobilization of appropriate financial resources to facilitate this.

In Durban, South Africa, the eThekwini Municipality identifies human health as a key component of its 'Headline Climate Change Adaptation Strategy' (Roberts, 2008). This strategy recognizes that the municipal government will have to respond to greater risks of heat-related deaths and illnesses, extreme weather (particularly the vulnerability of sewage networks and informal settlements to flooding), potentially reduced air quality and the impacts of changes in precipitation, temperature, humidity and salinity on water quality and vector-borne diseases. It also recognizes the need for public education, to develop community responses, to ensure that electricity supplies can cope with peaks, to promote more shade provision and increased water efficiency, to develop an extreme-climate public early-warning system and to facilitate research and training on environmental health.

Policy implications: Maintaining density whilst reducing vulnerability

As was clearly shown in the first sections of this chapter, de-densification of urban areas can lead to increasing greenhouse gas emissions—particularly related to the additional energy required for transportation. A particular challenge for urban planners and managers in low- and middle-income nations is to improve the quality of housing—and thereby increase resilience—for low-income urban residents living in inadequate shelter (meeting adaptation needs), whilst maintaining generally high density levels (meeting mitigation needs). What is certain, however, is that attempts at preventing urban growth by discouraging rural-urban migration with tactics such as evicting squatters and denying them services are futile, counter-productive and violate people's rights (UNFPA, 2007).

There are various strategies for improving slum settlements, including through investments by individuals and households and upgrading driven by community-neighbourhood investment and by external programmes. However, individuals and households cannot address the need for infrastructure at the scale of the neighbourhood (water pipes, sewers and drains, paved roads and paths, electricity, social services), and the most successful upgrading involves a combination of community/resident organizations and government agencies acting to address these issues. In many cases, as shown in the examples below, this approach can maintain densities whilst reducing vulnerability.

In Thailand, the Baan Mankong process constitutes a national approach to upgrading and providing secure tenure (Boonyabancha, 2005). In some cases, slum upgrading actually *increases* densification: In Charoenchai Nimitmai, the re-blocking process accommodated new residents as a means of reducing land costs. Technical solutions that facilitate maintaining density while also improving resilience can include in situ improvement, re-blocking, land-sharing and nearby relocation. However, Boonyabancha concluded (p. 39) that "finding technical solutions . . . is the easy part". The broader lessons learned from the Baan Mankong process are related to the importance of citywide programmes in which urban poor organizations are fully involved; the importance of horizontal linkages between peer groups in the city; and the importance of enhancing the 'belonging' of urban poor groups.

In Namibia, progressive policies for slum upgrading involved reducing the official national minimum plot standard, thereby expanding the legal options for increasing densities (Mitlin and Muller, 2004). Instead of a minimum standard of 300m^2, the option was provided for serviced plots of 180m^2 with communal water points and gravel roads. Frameworks were also provided that facilitated group purchase or lease of communally serviced land and smaller plot sizes, meaning that families can live legally while upgrading services as and when this can be afforded.

An additional aspect of slum upgrading and densification that needs to be addressed is the design of low-income housing. Nnaggenda-Musana (2008) suggests that most 'low-cost' housing design proposals are little more than smaller versions of higher income housing designs, resulting in sprawling low-cost housing that leads to longer travel distances for low-income urban residents and increased costs for the provision of services and infrastructure. Longer travel distances increase both emissions and cost problems. New house types for low-income households can reduce infrastructure and transport costs while at the same time preventing encroachment on agricultural land. In addition, architects have rarely learned from the strategies used by urban poor households to keep their buildings as comfortable as possible in a range of climate scenarios; Jabeen

(2009) shows some of the strategies used by households in Dhaka, Bangladesh, to keep indoor temperatures relatively cool, even when outdoor temperatures are particularly hot.

Conclusion

Urban areas, particularly in low- and middle-income nations, face a variety of challenges. Perhaps the most striking is the tension between meeting the twin demands of generating urban economic growth and meeting the needs of low-income urban residents (Parnell and Robinson, 2006; Pieterse, 2008). These issues are related to a variety of climate change challenges as well, particularly in regard to ensuring that urban growth occurs in a 'climate friendly' manner and that urban housing and infrastructure are 'climate proof'. Deeper consideration of demographic issues and their implications for mitigation and adaptation can help to resolve these tensions.

This chapter has examined the relationship between urban density and climate change, and has considered this relationship from the perspectives of both mitigation and adaptation to climate change. Future patterns of greenhouse gas emissions and the consequent climate change will be driven substantially by the activities now taking place in urban areas; similarly, the ways in which climate change impacts the lives and livelihoods of more than half of the world's population will also be mediated through actions that are taken—or not taken—in towns and cities. It is clear that there is no 'ideal size' for urban settlements—indeed, "different sizes and shapes of cities imply different geographical advantages" (Batty, 2008, p. 771). In addition, there is no ideal density for cities and towns—instead, broader issues of urban form and structure are equally or more important.

There is also a complex series of interactions among urban density, economic status and greenhouse gas emissions. The residents of the densely populated cities of low- and middle-income countries are generally wealthier than residents of the hinterlands, yet they are far less wealthy than residents of the less densely populated cities in high-income countries. This illustrates that the relationship between urban density and greenhouse gas emissions is not straightforward: In low-income countries, residents of denser settlements are likely to have higher per capita emissions as a function of their greater wealth than residents of surrounding areas, whereas in high-income countries, residents of denser settlements are likely to have lower per capita emissions than residents of surrounding areas as a result of smaller housing units and greater use of public transportation systems.

In relation to the impacts of, and adaptation to, climate change (and other environmental hazards), density has another set of effects. The extremely high population densities of many urban areas in low- and middle-income countries contribute to environmental health problems and may concentrate risk in particularly vulnerable locations, and any potential sustainability gains from even greater densification are likely to be limited. Indeed, "under these circumstances the merits of urban densification postulated for developed country cities seem far less convincing in the context of developing countries" (Burgess, 2000, p. 15).

In summary, density is one of several major components affecting the ways in which urban areas will both influence and be affected by a changing climate. Adopting 'increasing densification' as a strategy without assessing other factors such as the distribution of employment opportunities and the nature of transportation systems is not likely to provide lasting sustainability or resilience benefits. Yet, in association with a wider awareness of urban form and process, well-planned, effectively-managed and densely-settled towns and cities can help to limit greenhouse gas emissions and facilitate resilience to the challenges of climate change.

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