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An Overview of Urban Environmental Burdens at Three Scales: Intra-urban, Urban-Regional, and Global

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This article focuses on the importance of scale to understanding urban environmental burdens and sustainability. It examines urban environmental burdens at three different scales: (1) within urban areas, where the central concern is how the quality of urban environments affects the lives of the people who live in them; (2) within urban regions, where relations between urban development and the state of adjoining ecosystems, resources , and waste sinks comes into focus; and (3) globally, where the emphasis is on the impact of urban production and consumption on global processes and distant resources. The spatial dimensions to urban environmental burdens are shown to be important ecologically, economically, and even politically. By focusing on a particular scale, it is easy to construct misleading accounts of the qualities of urban settlements that generate the environmental burdens. It is easy, for example, to present either urban poverty or affluence as the most serious threat to the environment, depending on whether the focus is on local or global environmental burdens. The article concludes with a comment on the implications for urban environmental agendas.

Keywords: Urban, Environment, Sustainable, Cities, Ecological footprint.

There is a long history of environmentalists presenting urban settlements in purely negative terms. This article follows a more recent tradition that recognizes that urban settlements are unsustainable in and of themselves, but also that they may provide the key to moving towards a more environmentally sustainable world (Rees and Wackernagel 1996; Satterthwaite 1997). Urban residents and their activities undoubtedly create environmental burdens, but even from an ecocentric perspective there should be no presumption that these burdens would be less if the same people and their activities were dispersed across the rural landscape. Urban settlements concentrate environmentally harmful people and activities, but they also concentrate the people who must change their ways if environmental burdens are to be reduced, and they can be made to provide opportunities and incentives for them to do so.

1. Environmental burdens in an urbanizing and economically growing world

People are growing in number, producing and consuming more, increasingly likely to live in urban areas, and placing growing pressure on the global environment. Behind these widely accepted trends lie complex and uneven processes that are difficult to define and disentangle. There is not even agreement on the meaning and measurement of urbanization, or on the relationship between economic

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production and human well-being, let alone on the consequences of urbanization and economic growth for the environment or the well-being of future generations.

It is widely agreed that, compared to rural settlement, urban settlement is associated with higher population density, larger settlement size, more centralized administrative functions, and a less agricultural occupational profile. But different countries, and in some cases even different agencies within countries, apply different definitions of urban, in terms of both the criteria applied and the cut-off points used (United Nations 2002b; Cohen 2004). In effect, international statistics are forced to rely on country-specific definitions that display numerous arbitrary differences (Montgomery et al. 2003).

The complex of demographic, social, and economic characteristics that once maintained a multidimensional urban/rural distinction has been unraveling for some time (Pahl 1965). Especially in affluent countries, agriculture has been becoming more industrial, and a great many rural dwellers have what would once have been considered urban occupations and lifestyles (Friedmann 2002). Urban settlements, on the other hand, have become less industrial. Moreover, better transportation and communications have blurred the distinction between urban and rural living.

Urban regions and extended metropolises have grown in importance (McGee and Robinson 1995), and in Asia the term *desakota*, combining the Indonesian words for village (*desa*) and city (*kota*), was coined to capture the emergence of new forms of economic interaction characterized by a concentrated mix of agricultural and non-agricultural activities that often stretches along corridors between large city cores (McGee 1987, 1991; Sui and Zeng 2001). Alternatively, the importance and special character of smaller urban centers is often neglected. Even in demographic terms the distinction between urban and rural fails to capture the changing densities and patterning of human settlements (Hugo, Champion, and Lattes 2003).

The concept of economic growth is also contended, particularly when taken as a goal that governments should aspire to (Lawn 2003). Few economists would claim that per capita gross national product is a good measure of human well-being, let alone "sustainable" well-being (Asheim and Buchholz 2004; Hamilton and Dixon 2003). Indeed it was not designed to measure well-being (Beckerman 1988). Among other things, the importance of inequality has long been recognized, and recent decades have brought increasing attention on the importance of maintaining social and environmental capital. Even for identifying households and individuals living in poverty, income levels can be very misleading (Satterthwaite 2004), and other dimensions of poverty such as social exclusion and environmental deprivation are receiving greater recognition (Rakodi 1995; Wratten 1995).

Yet even if concepts like urbanization and economic growth do not do justice to the complex shifts in human patterns of movement, settlement, and well-being, by virtually any measure urbanization and economic growth have been two of the most striking trends of the past century. They have occurred very unevenly, but usually in tandem. Over the course of the twentieth century, it is estimated that the world's urban population increased almost fifteenfold, rising from less than 15 percent to close to half of the total population. Over the same period, gross domestic product (GDP) at constant prices increased about 19-fold, or an almost five-fold increase in GDP per capita—with, on average, faster growth in rich than in poor countries (International Monetary Fund 2000). To a significant degree, rapid urbanization

has taken place in the locations where there has been rapid economic growth (Satterthwaite 2002). The relatively close relationship is hardly surprising: for much of the twentieth century, modern economic growth was predicated on industrialization, commercialization, trade, and the use of fossil fuels, all of which have helped to drive urbanization.

The expansion of urban land area is often presented as an environmental impact of urbanization, though urban settlements still cover less than 3 percent of the earth's total land area (McGranahan et al. forthcoming). Urban land area is a very poor indicator of the environmental burdens imposed by an urban settlement, however. On the one hand, many of the burdens of urban activities fall well outside urban boundaries, and depend upon the character and intensity of the activities. On the other hand, urban environmental burdens include hazards in the living and working environments in urban areas, which vary within and between urban areas.[1]

William Rees has compared urban settlements to anthills or cattle feedlots, characterized by extraordinarily high densities of their keystone species, and sustained primarily by biophysical processes that take place outside the high density areas themselves (Rees 2003). A city's urban land area only represents a small share of the land whose services are required to sustain the city; what has come to be termed its "ecological footprint" (Rees 1992). Moreover, as an urban area develops it leaves it imprint on the surrounding countryside in numerous ways, only some of which are directly related to the demands of the urban residents themselves (Cronon 1992).

Just as it is important to look to the extra-urban, it is also important to look at intra-urban scales, and in particular at urban environmental health profiles and how they vary within and between urban areas. Just as two cities of the same area can have very differently sized ecological footprints, so they can have very different environmental health profiles. Moreover, while more environmentally minded urban policies can reduce both environmental health risks and ecological footprints, they do not necessarily move together. Indeed, historically urban environmental burdens at different scales have often tended to move in opposite directions, as will be described in the following section.

2. The importance of scale

Urban environmental burdens vary enormously in scale. If fecal material from a latrine contaminates the water in a neighbor's well, the burden is, at least in the first instance, very localized. If, on the other hand, urban greenhouse gas emissions contribute to climate change, the burden is globalized. And to complicate matters, if an urban enterprise contaminates local wells and ships its products to distant cities, this is a local environmental burden from the perspective of urban production, but a global burden from the perspective of urban consumption.

There is also enormous variation in the severity of the environmental burdens cities impose, even among cities of similar populations and extents. Some urban and neighborhood environments are extremely unhealthy to live in, while others are not. Some urban centers release large quantities of waste

1. Urban environmental burdens can be defined as threats to present or future human well-being (or other things of value), arising from damage to the physical environment caused directly or indirectly by activities undertaken in urban areas (IIED 2001).

into the surrounding region, and deplete regional resources, while others of the same size are far less burdensome. And while the ecological footprint of virtually every urban settlement is larger than its urban area, ecological footprints also vary enormously.

The severity of urban environmental burdens at each scale depends upon the geographical setting; the social, economic, and technical characteristics of the urban settlement(s); and the measures taken to reduce the burdens. The severity of the burdens at different scales are interrelated, but are not always positively correlated. Reducing local environmental burdens, for example, can increase or reduce large-scale burdens, depending in part on the specific measures taken to relieve the local burden. Introducing a piped water and sewerage system is likely to decrease the environmental health burdens within the city, at the cost of increasing the resource and waste burdens the city imposes on the region. On the other hand, increasing fuel efficiency or switching to cleaner fuels is quite likely to improve air quality within the city, and also to reduce greenhouse gas emissions and their contribution to global burdens.

The relationship between per capita income and the overall per capita environmental burden of an urban settlement is ambiguous, but there is a tendency for the environmental burdens of more affluent urban settlements to be more dispersed and delayed (McGranahan et al. 2001). In cities where average incomes are very low, local environmental health burdens relating to poor sanitation and indoor air pollution tend to be severe, while the global pressures resulting from resource use and waste generation tend to be low. On the other hand, in cities where average incomes are very high, environmental health burdens tend to be low, while consumption tends to be high, leading both directly and indirectly to high levels of resources use and waste generation. A number of studies have found that some intermediate-scale burdens, indicated for example by urban air pollution concentrations, first rise and then decline with income (the environmental Kuznet's curve), although these findings have been challenged and the relation to scale has not been generally accepted (Stern 2004).

The relationship between income and the scale at which urban environmental burdens occur also involves the increasing separation of consumption from locally polluting production, with productive activities that cause pollution more likely to be displaced from affluent settlements. There are indications that "dirty" industries are moving from more affluent to lower income countries, although the evidence is not easy to interpret and other factors often seem to dominate (Cole 2004). More specifically, for air pollution there is evidence that income starts to be associated with environmental improvements earlier in the case of pollutants for which spatial separation is relatively easy (Khanna and Plassmann forthcoming).

The different scales at which urban environmental burdens occur are not only important because of the relation to economic growth. A recent book on assessing ecosystems and human well-being has a chapter outlining the importance of multi-scalar assessments (Millennium Ecosystem Assessment 2003, ch. 8, "Dealing with Scale"), which observes that:

- "Big" processes tend to be slower than "small" processes;
- By focusing on one scale, assessments are likely to neglect critical processes at other scales;
- Inter-scale effects are often critical;
- The choice of scale is not politically neutral;

- Many environmental problems arise from a mismatch between the scale of the burden and the scale at which the response is taken.

All of these observations apply to urban environmental burdens, and are examined in turn below.

"Big" processes tend to be slower than "small" processes

The burdens that urban consumption and pollution impose globally tend to be of longer term than the burdens that remain localized. Thus, global burdens, such as climate change and the global depletion of non-renewable resources, are long-term threats to future generations, while most of the local environmental health hazards in and around people's homes and workplaces affect the well-being of those exposed within a fairly short time.

By focusing on one scale, assessments are likely to neglect critical processes at other scales

Focusing on urban environmental burdens that are local in scale draws attention to intra-urban environmental health hazards, but can lead to the neglect of the larger-scale problems that result when, for example, local sanitation problems are resolved by conveying sewage to be carried away by rivers, or local air pollution problems are resolved by introducing taller stacks or forcing polluting industries to locate downwind of the town center. On the other hand, focusing on urban environmental burdens at the global scale draws attention to the consumption of internationally traded resources and global pollutants (for example, greenhouse gas emissions), but can lead to the neglect of local environmental health hazards, particularly when these vary by location.

Inter-scale effects are often critical

It can be misleading to identify burdens exclusively with one scale. In many ways global warming is an archetypal global burden, since the mechanism is so clearly global in scale. The risks, however, are likely to be very location specific. Bad sanitation, on the other hand, is an archetypal local burden, since it involves local conditions allowing diseases to spread among local residents via fecal-oral routes. Yet when unsanitary conditions extend over large areas, there is a risk of epidemics or even pandemics, potentially threatening people on the other side of the globe from where the outbreak originated (Haggett 2000). Furthermore, as noted above, international trade often links the local environmental burdens of production in one place to consumption in a different part of the globe, creating a global burden from a consumption perspective out of a local burden from a production perspective. For more on these contrasting perspectives, see section 5 below

The choice of scale is not politically neutral

Environmental burdens usually have a public aspect, but fall unequally, some more unequally than others. The scale at which environmental burdens are being assessed not only influences the scale at which public responses are likely to be conceived, but the types of inequalities that are likely to be observed. Thus, for example, measures to improve environmental conditions in low-income neighborhoods and cities are easier to justify when the focus is on localized environmental burdens, while measures to reduce burdens on future generations are better served by a global focus. Alternatively, a local focus is more favorable to the narrow pursuit of economic growth, while taking a global focus can support a stance more critical of high consumption patterns. It is no coincidence that

anti-growth environmentalists (for example, Daly 1996) are primarily concerned with global environmental burdens, while pro-growth environmentalists (for example, Lomborg 2001) are more concerned with local environmental burdens—though it is often difficult to tell which came first, the focus or the attitude to growth. Moreover, environmental politics often center on the shifting environmental burdens, which involves changing scales.

Despite all of the substantial differences between environmental burdens at different scales, there are also important similarities. On the one hand, there are structurally similar institutional obstacles to reducing urban environmental burdens at every scale. On the other hand, urban settlements provide opportunities for reducing environmental burdens at every scale, and it cannot be presumed that a more rural population distribution would create less severe burdens, locally, regionally, or globally.

At every scale, urban environmental burdens are difficult to address because they:

- Involve complex and poorly understood processes;
- Fail to conform to the boundaries of private property, circumventing market mechanisms and creating economic externalities (consequences of one party's action or decision on another party's well-being that occur without effective negotiation or agreement on compensation);
- Fail to conform to the boundaries of administrative responsibilities, circumventing effective public-sector management, and creating what could be termed political externalities (consequences of actions undertaken within one administrative unit on the ability of another administrative unit's ability to meet its goals);
- Fall most heavily on the politically or economically weak, although in the case of local burdens the most vulnerable are the urban and peri-urban poor, while in the case of global burdens, future generations are also extremely vulnerable.

While these obstacles are difficult to overcome, they are not specific to urban living. Indeed, while urban settlements can be very difficult to manage effectively and equitably, at every scale, they have a number of advantages over rural settlements when it comes to reducing environmental burdens. The following list has been adapted from McGranahan, Satterthwaite, and Tacoli 2004.

For *urban* and *peri-urban* environmental living conditions:

- Returns to scale and proximity yield lower costs per capita of providing piped treated water, sewerage systems, waste collection, clean fuels, and many other environmental services;
- There are more possibilities for local governments to fund or manage other forms of infrastructure and services that reduce environmental health risks (for example, enforce pollution control and occupational health and safety).

For *regional* environmental burdens:

- High urban population densities can reduce the per capita demand for occupied land;
- The concentration of major polluters facilitates pollution control.

For *global* environmental burdens:

- Compact urban settlement patterns reduce transport distances, increasing opportunities for more energy efficient public transport and thereby reducing carbon emissions;
- Economies of scale and agglomeration make electrical co-generation possible and facilitate the use of waste process-heat from industry or power plants for local (neighborhood) water and space heating, again reducing carbon emissions.

3. Urban areas as habitats for humans

In urban areas, humans are the defining species and built-over land is the defining land use. Yet most human evolution took place before sedentary living, let alone urban living, became the norm, and urban living has historically posed serious physical challenges for humans. Many non-human species, on the other hand, have adapted to urban living. Urban ecological landscapes are characterized by patchiness and variation (Collins et al. 2000) and by greater species richness than in the countryside (Rebele 1994). With a wide range of contrasting habitats, there is more scope for biodiversity in urban areas than in, for example, agricultural monocultures. Even urban core areas usually contain a mix of land uses, though it is in peri-urban areas that variability and land use change is likely to be at its height.

The relationship between humans and the other species in their settlements has always been critical to human well-being, even if people have not generally been aware of the connection, and not all of the relationships have been positive. It has been proposed, for example, that one of the reasons why New World inhabitants came to be decimated by Old World diseases when the two populations came into contact, was that only in the Old World had people shared their settlements with domesticated animals. This led to the emergence of diseases that eventually began to spread from person to person: measles and smallpox from cattle, influenza from pigs or chickens, the common cold from horses, and most respiratory infections from one domestic animal species or another (Watts 2003; Cohen 1989). In the New World people had not been exposed to these diseases, which made them vulnerable when the two populations met. The risk of avian flu, a very contemporary concern, also derives from close relations between humans and other species in human settlements. Even when human settlements have not been the source of the initial outbreak, they affect disease transmission, as in the case of HIV/AIDS.

Many of the more serious infectious diseases can only have emerged as a serious threat to health when people began to congregate in large enough settlements to allow the infection to be maintained (Cohen 1989; Mascie-Taylor 1993). Research on measles, well before vaccinations altered transmission patterns, found that the time between epidemics was inversely proportional to the town's population, and implied that above a population of about 250,000, a continuous chain of infection would be maintained. For a number of infectious diseases, large cities can act as reservoirs of disease, and then spark an epidemic when the susceptible population builds up above a critical level (Haggett 2000). Urban networks can then become conduits in the spread of infectious diseases regionally or even globally.

Disease transmission also depends on how urban environments are managed. Historically, the most serious urban environmental health hazards have involved unsanitary conditions, including inadequate access to clean water, which facilitate the spread of fecal-oral diseases (Cairncross and Feachem 1993). Unsanitary conditions are believed to be a major factor in the urban health penalty—that is, the higher

mortality and morbidity rates found in urban than in rural areas—that burdened so many urban areas well into the nineteenth century.

The sanitary revolution that began in some of the more affluent cities towards the end of the nineteenth century provides a revealing example of how better governance and urban environmental management can not only overcome but even reverse the disadvantages of urban living. In England, for example, there is evidence that despite their economic success urban areas were becoming increasingly unhealthy places to live for several decades of the nineteenth century (Szreter 1997). The reforms initiated in the second half of the century, which eventually brought urban health up and above that of rural areas, were closely linked to changing urban politics and governance (Szreter 2002).

From the perspective of environmental conditions in areas adjoining urban settlements, the reforms of the sanitary revolution added to the urban burden. Sewerage networks carried human waste out of the cities and released them untreated into nearby waterways. Piped water networks drove the search for more and more distant water sources. What we would now characterize as ecological concerns, such as over the disruption of natural cycles and the loss of soil nutrients, were voiced at the time. Edwin Chadwick, perhaps the most influential sanitary reformer, had hoped to recycle sewage onto the fields. As it transpired, however, sanitary reform led to major improvements in urban health, but at the cost of deteriorating environmental relations with the surrounding areas.

More important from the perspective of urban areas as habitats for humans, water and sanitation conditions remain extremely unhealthy in a great many low-income settlements in Africa, Asia, and Latin America (United Nations Human Settlements Programme 2003; Hardoy, Mitlin, and Satterthwaite 2001). Official figures put the number of urban dwellers without improved water supplies at 173 million (WHO and UNICEF 2000), though it has also been estimated that upward of 700 million are without adequate provision (United Nations Human Settlements Programme 2003). Despite widespread agreement that improvements are necessary, the urgency evident in the nineteenth and early twentieth centuries is missing, in both local and international policy arenas. True, one of the 18 international targets now associated with the Millennium Declaration adopted by the world's leaders at the Millennium Summit of the United Nations in 2000 was to "halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation".[2] But, most of the policy debate in the water sector still centers on issues of water resource management or private-ector participation, neither of which is critical to sanitary improvement in deprived areas (McGranahan and Satterthwaite 2003). Even within the water sector, it is widely recognized that sanitation receives insufficient attention.

At least part of the reason why the urgency of sanitary reform has declined, despite so many evident deficiencies, is that fecal-oral diseases less often give rise to epidemics that threaten those who do not live in deprived settlements (Cairncross and Feachem 1993). Endemic diseases that are rarely fatal except to infants and children in low-income neighborhoods do not motivate international agencies, national governments, or even local governments in the way that epidemics did historically, as they spread from city to city. In September 1848 the *Times* of London described cholera as "the best of all

2. The reference to sanitation was added after the World Summit for Sustainable Development in Johannesburg in 2002—see the Millennium Development Goals, described at http://www.developmentgoals.org (accessed 24 November 2004).

sanitary reformers" (Wohl 1983), and to this day most governments can find extra resources for improving sanitation when a cholera epidemic threatens.

The crisis-driven sanitary reforms of the nineteenth century had their problems too. The epidemics helped to reinforce elite stereotyping of slum residents as dirty, morally suspect, and dangerous to deal with, just as contemporary epidemics reinforce prejudice and discrimination against deprived groups (Briggs and Mantini-Briggs 2003). Equally important, fears of epidemics helped to justify a top-down approach still evident in most water and sanitation utilities. Even the technologies employed, such as piped water and sewerage networks, were attractive in part because they allowed the technical and managerial responsibilities for urban water and waste flows to be shifted from the residents to engineers.

Recent decades have seen considerable debate over the institutional forms appropriate for managing urban water and sanitation systems. Private-sector participation has been vigorously promoted from some quarters, especially in the World Bank (Finger and Allouche 2002). However, while the choice between public and private utility operators is clearly of great importance to vested interests within the water sector, it not of obvious significance to those deprived of water and sanitation, who generally remain unserved whether the water and sanitation utilities are public or private (Budds and McGranahan 2003). Moreover, while private-sector participation has generated the most heated debates, some of the most notable successes have come from initiatives directly supportive of community organization and action (Mitlin and Satterthwaite 2004). Even the World Bank, in its recent World Development Report on *Making Services Work for Poor People*, argues that better services to low-income groups can only be achieved by "by putting poor people at the center of service provision: by enabling them to monitor and discipline service providers, by amplifying their voice in policymaking, and by strengthening the incentives for providers to serve the poor" (World Bank 2003).

While the history of infectious diseases has been closely bound up with the history of human settlements, for most people urbanization is more closely associated with the chemical pollution of air and water. Ever since people began to cook food and warm themselves around fires, rural dwellers have been exposed to health-threatening air pollution. Even today, rural exposure to indoor air pollution is probably more of a health burden than urban ambient air pollution (Ezzati et al. 2002). But industrialization and motorization brought new, more visible, and more public forms of pollution. While sanitary reformers of the nineteenth century did often try to introduce pollution controls, the politics were not favorable (Mosley 2001). Even more than in industrializing and motorizing cities today, smoke and chemicals were associated in many people's minds with economic success. There was no equivalent to water pipes and sewers promising to address air pollution problems and to shift the intellectual and practical burdens of environmental management from individuals and enterprises to experts in a government agency or utility. It was not until the middle of the twentieth century that a number of governments, spurred on by the evidence of high mortality rates resulting from severe air pollution episodes in a few major cities, were put under pressure to enact laws and introduce regulations capable of reducing the concentrations of the best-known pollutants (McGranahan and Murray 2003). While exposure to chemical pollution remains a significant urban health issue, in countries that have taken strong measures to reduce emissions, reductions in concentrations of the targeted pollutants have been appreciable.

Even in affluent countries where ambient air and water pollution are increasingly regulated, chemical waste disposal can lead to serious and often inequitable urban environmental health burdens, and the urban developments can undermine public health. In the United States, for example, the "environmental justice" movement emerged in response to inequalities in exposure to environmental health hazards (Shrader-Frechette 2002), and serious questions have been raised about the implications of urban sprawl for human health (Frumkin, Frank, and Jackson 2004). Indeed, while local environmental health hazards may be far more severe in the urban settlements of low-income countries—and particularly their more deprived neighborhoods—they remain an issue in virtually all urban areas.

4. Urban environmental relations with their adjoining regions

Urban settlements have always been dependent on their hinterlands, as a source of natural resources and rural products, as a sink for wastes, and as sites for expansion. While the distances involved have grown in recent centuries, and an increasing number of products and resources can be sourced globally, urban regions remain critical loci of urban–rural flows and environmental impacts.

The metabolism of an urban area, described by the flows of energy and materials in and out of a settlement, is revealing of the environmental burdens it is likely to impose on ecosystems beyond the urban boundaries (Douglas 1981; White 1994; Decker et al. 2000; Newman 1999). The linear flows characteristic of urban external relations, as opposed to the circular flows characteristic of stable ecosystems, reflect the nature of the regional environmental challenges urban development poses: resources are susceptible to depletion and waste sinks to continued accumulation. The multifold increase in throughput per capita observed over the last few centuries is indicative of the size of the challenge.

A recent review examined the energy and material flows in and out of the world's 25 largest cities. Water was estimated to account for about 90 percent of all material entering megacities, and it was found that these cities were usually more dependent on their proximate environments for water and waste processing than as a source of fuel, food, or aggregates (Decker et al. 2000). Except for biofuels, fuels are now only rarely sourced locally, but urban air pollution from fuel combustion can contribute to direct exposure in the adjoining region, and to acid rain, often at a considerable distance from the polluting location. Food and other agricultural products are often imported from distant locations, but urban development does often lead to radical transformations in land-use patterns in the surrounding region. The following sub-sections focus on water, fuel, and land use in turn.

4.1. Water

Although urban water consumption is usually several times smaller than the amount of water consumed in irrigated agriculture (Gleick 2003), getting sufficient water of adequate quality to meet growing demand has long been a challenge for urban settlements. The utilities that operate urban piped water networks have traditionally tried to meet this challenge by investing in water infrastructure so as to bring greater quantities of water from further away. Where water infrastructure is highly developed and urban centers are networked together, local variation in supply/demand balances are merged, and water shortage becomes a regional phenomenon. The tendency for urban settlements to tap more-distant

sources for their water supplies is not confined to affluent countries. Research on the changing urban water systems in Africa, where insufficient infrastructure is often cited as a major problem, indicates that while in the early 1970s many major cities still used groundwater supplies as their primary water sources, by the 1990s the primary water sources were more likely to be rivers, and increasingly these river sources were more than 25 kilometers away (Showers 2002).

Although regional water scarcity is a very serious problem in many parts of the world, it does not explain the fact that so many urban residents do not have adequate water supplies. Indeed, for urban dwellers in countries subject to water stress—defined as less than 1,700 cubic meters per capita per annum of renewable fresh water resources—the official figures indicate slightly higher coverage rates (McGranahan 2002). For those without improved water supplies, water resource problems can be particularly severe. The amount of clean water households need to stay healthy is very small compared even to urban water demands, however, and the challenge for deprived households is to get access to the potable water supplies that do exist.

In any case, getting sufficient water to urban settlements is only one of the urban water challenges. Water enters and leaves urban areas in almost equal quantities, but while it is flowing through urban areas it is likely to be used, polluted, and otherwise transformed. Urban areas usually have a high percentage of paved areas; they concentrate rainwater rather than dissipate it. This can intensify flooding and cause flash floods. Changes in the water flows can also affect downstream fish stocks, recreational opportunities, and biodiversity. Sewers convey human waste out of urban locations, often releasing it untreated into local waterways or coastal waters. Human waste not only poses a health risk for people who might come to ingest the contaminated water, but can also cause eutrophication and damage to aquatic ecosystems downstream. Chemical water pollution is also a major problem, particularly around large industrial centers. When cities and surrounding rural areas are competing for water resources, ecological water requirements (the water needed to maintain ecosystem function and local hydrological cycles) are often neglected.

Integrated water resource management has been advocated as a means of addressing these regional water issues. By getting different water stakeholders to negotiate acceptable solutions, and imposing regulations when necessary, basin-level authorities are in a good position to address urban-region water issues. In the Plan of Implementation of the World Summit for Sustainable Development (United Nations 2002a), countries are exhorted to develop integrated water resource management plans by 2005. The natural scales for water resource management are river basins and catchment areas, and the Plan of Implementation explicitly indicates that countries should “adopt an integrated water basin approach” (ibid., 21). However, river basin and catchment management organizations are unlikely to have the political power to address issues of equitable access to urban water networks. In effect, while equity is often emphasized as a goal of integrated water resource management, organizations adapted to the scale most suitable to urban-region issues are unlikely to be able to address the most critical intra-urban issues.

4.2. Fuel consumption and air pollution

Fossil fuels have not only enabled radical changes to urban form, but have also broken urban dependence on local energy sources. The urban settlements where resource links remain strong are in

those low-income countries where charcoal is an important fuel for urban households. Charcoal is sometimes blamed for "rings" of deforestation around some African cities, although charcoal producers are often not as destructive as they are portrayed to be (Hosier 1993). Electricity produced from hydropower also draws on regional resources, and dams can have major environmental consequences. Otherwise the strongest environmental links between urban energy use and environmental conditions in the surrounding region derives from air pollution, which results primarily from fuel combustion.

Certain types of air pollution involve transformations in the environment that take place away from the site of emission (Smith and Akbar 2003). For example, it can take several hours for ozone to form, creating concentrations quite far from the site where the precursors were originally emitted. Some particulates are also formed through chemical reactions in the atmosphere. These particulates and ozone may be created outside of the urban centers where the emissions originated, imposing health risks in areas downwind, as well as damage to crops. Acid depositions (for example, acid rain) are the result of emissions of oxides of sulfur and nitrogen, which can be carried hundreds of kilometers by the air. In addition to harming crops, acid depositions can disrupt natural ecosystems.

There is the potential to use cross-scale effects to exploit synergies and find the best means of reducing air pollution problems at all scales. Unfortunately, there is still a tendency to treat these air pollution issues separately, or to assume that reducing air pollution at one scale also reduces it at others. Historically this has not always been the case. Higher stacks, for example, were used for many years to reduce local concentrations, at the cost of allowing the pollution to disperse over longer distances. Even greater energy efficiency does not always reduce air pollution at every scale—a wood stove that transfers a greater share of the fuel energy to heating a pan, for example, may achieve this at the cost of greater emissions of the products of incomplete combustion because the combustion site is more confined.

Unlike watersheds, airsheds are not easy to identify, and they do not provide the spatial basis for air pollution management organizations. National governments have been more important, as sources of both local air pollution regulation and of global air pollution governance. On the other hand, global air pollution governance (including negotiation over greenhouse gas emissions) remains rudimentary, local air pollution regulation is still a challenge, and efforts to coordinate measures targeting different scales have barely begun. And as with water, there is little evidence that the higher-level institutions responsible for air pollution management will be in a position to address the indoor air pollution burdens that tend to be more severe in low-income settlements—and especially rural settlements.

4.3. Urban development and changing regional land use

Urban land areas have been expanding, historically because of population growth (which is still the main driver of urban expansion in many lower-income countries), and more recently as the result of increasing numbers of smaller households and urban sprawl (especially in some higher-income countries). A disproportionate share of urban area is located in coastal zones, and the loss of wetlands to

urban expansion is of special concern.[3] In North America, where compared to other continents a large share of the urban population is located in agricultural zones, and urban sprawl is leading to the expansion of what are already some of the world's least densely settled urban areas, the loss of agricultural land to urban expansion is also of particular concern.

While urban land area is undoubtedly increasing, it is misleading to draw a sharp distinction between environmental impacts that involve rural land being converted to urban land, and those that involve rural (or for that matter urban) land whose usage is being influenced by urban development. First, urban boundaries are arbitrary. There is not even agreement on the criteria by which urban areas should be identified—whether, for example, boundaries should be based on population densities, land cover, the occupational profile of residents, administrative limits, or some combination. Official urban boundaries rarely match the extent of contiguous built-up area; they may be smaller (as urban development has spilled over boundaries set many years ago) or larger (as urban boundaries have been defined that encompass large areas of agriculture, forest, and water). In addition, an aerial view of a major urban regions is unlikely to display a concentrated urban center surrounded by countryside; more likely there will be a complex spatial pattern of urbanized and non-urbanized areas, with built-up areas stretching along major transport corridors for long distances, and green areas reflecting planning decisions as much as distance from an urban center. In addition, it is common for residential communities and industrial and commercial concentrations to develop close to major cities, but separated from the main built-up area.

In any case, urban expansion transforms not only the land that becomes urbanized (however defined) but also the land whose use is determined by demand both for land-based products and for resources (such as water) whose appropriation changes land-use patterns. Large demands are made on the regions around cities for building materials and landfill as a result of the construction of buildings, roads, industries, and other components of the urban fabric. Many of the urban-generated solid wastes impact the surrounding region—for instance, urban solid wastes are often transported to parts of the surrounding region and disposed of at open-air sites with little or no provision for protecting nearby soil and water from contamination. Moreover, urban development changes agricultural land-use patterns. As Cronon has illustrated for the case of Chicago, rural environments and ecologies reflect demands and innovations that occur in nearby urban centers (Cronon 1992).

5. Urban consumption and global ecological footprints

Contemporary urbanization is based upon that quintessentially global resource, petroleum. Petroleum products have not only fueled the transportation systems that enable modern urban systems to function, and are a dominant influence on urban form, but they fuel many of the productive activities undertaken to meet urban demands. However, petroleum consumption itself only accounts for a small share of the burden urban consumption is placing on the world's resources and waste sinks.

3. The boundary limits used for mapping coastal zones in the Millennium Ecosystems Assessment were area between 50 meters below mean sea level and 50 meters above the high tide level or extending landwards to a distance of 100 kilometers from the shore (Millennium Ecosystem Assessment 2003). Globally, an estimated 10 percent of land in the coastal zone is urban, as compared to less than 3 percent overall (McGranahan et al. 2005 forthcoming).

In principle, it is possible to assign environmental burdens to an urban settlement either by considering the impact of the transformations that take place within the urban settlement's boundaries or by considering all of the transformations undertaken globally in supplying the goods and services consumed by the settlement's residents. The former provides a more suitable basis for examining urban technologies and production patterns, and the environmental pressures exerted on the surrounding region. The latter provides a more suitable basis for examining lifestyles and consumption patterns, and the environmental pressures exerted globally to sustain the settlement's residents. Perhaps equally important, the former will tend to assign higher burdens to settlements where resource- or waste-intensive industries are concentrated, while the latter will tend to assign higher burdens to more affluent urban settlements. For the cities that industrialized early, there was a significant overlap between the two, but affluent cities are now unlikely to be centers of heavy industry.

Some of the differences between taking either a consumption or a production perspective on global urban environmental burdens can be illustrated with CO_2 emissions. A recent study of urban energy use and greenhouse gas emissions in Asian megacities has estimated the CO_2 emissions of Beijing, Shanghai, and Tokyo, distinguishing between the CO_2 emitted within the urban areas and the CO_2 emitted in supplying the demands of the people who live in these cities (Dhakal forthcoming). Table 1 is based on estimates calculated for this study.

Table 1. Carbon dioxide emissions per capita for Beijing, Shanghai, and Tokyo

	Beijing (1997)	Shanghai (1997)	Tokyo (1995)
CO_2 emitted in city (tons per capita)	6.4	7.8	4.9
CO_2 emitted in providing goods and services consumed in city (tons per capita)	8.3	11.6	12.1

Source: Data provided in Dhakal forthcoming.

Tokyo does comparatively well in terms of CO_2 emissions per capita, and as the wealthiest city it fares even better in terms of CO_2 emissions per unit of economic output. A detailed analysis of the changing sources of emissions over time indicates that emissions per unit of economic output have been declining in Beijing and Shanghai, but still remain far higher than in the major Japanese cities (Dhakal forthcoming).

On the other hand, as indicated in the second row of table 1, things look very different from a consumption perspective, with the highest emissions per capita associated with the far higher consumption levels of Tokyo. Indeed, while for Beijing the emissions associated with consumption are only 30 percent above the direct emissions per capita, in Tokyo this figure rises by almost 150 percent.

Measuring the burden of the CO_2 emissions brought about by an urban settlement's consumption is complicated by data problems, issues of imputation (that is, whether it is misleading to assign the CO_2 emitted in producing a good to the end consumer), and uncertainty about the effects (that is, climate change and its consequences). On the other hand, the impacts of CO_2 emissions are clearly externalities, since CO_2 is emitted without any negotiation or consent on the part of those who will be affected by

climate change. This is not true for all consumption-driven environmental pressures, however, and in many contexts it is important to consider the economic institutions through which the pressures of consumption have their environmental consequences, even if these institutions are located elsewhere.

When demand increases, private property and markets can yield higher prices rather than higher consumption, and higher prices can stimulate the development and use of substitutes or alternatives. Similarly, governmental and common property arrangements can operate to prevent resource degradation and waste generation. There are limits to substitutability, especially at the global scale. Markets do not just stimulate resource-conserving innovation, they encourage competitive enterprises to reduce costs, even when this means seeking out poorly managed resources and locating waste-generating processes where wastes are poorly controlled. However, while resource use and waste production have physical consequences whatever the institutional form, it is important to recognize that the link between consumption and resource use is not as straightforward as physical accounting systems might seem to suggest. For example, physical accounting relates consumption in the present with resource use in the past, while an economic analysis of the consequences of the same consumption will link it to resource use in the future, and these two resource uses need not be the same. Nevertheless, physical accounting can provide very useful indicators of environmental burdens.

Various indicators have been developed in order to estimate the aggregate environmental burdens of urban settlement, often applying a variant of the Commoner-Ehrlich equation: $I = PAT$, where I is the environmental impact, P is population, A is affluence measured as consumption or production per capita, and T an environmental impact coefficient.

The best-known indicator developed specifically with urban settlements in mind is the ecological footprint, although several other indicators have been adapted to urban applications (Nijkamp, Rossi, and Vindigni 2004). The ecological footprint has been defined as: the area of land "required, on a continuous basis, to produce the resources that the population consumes, and to assimilate the wastes that the population produces, wherever on Earth the relevant land/water is located".[4]

Current accounting procedures for ecological footprints include built-up area and area under crops, under pasture, under forest, and under fisheries, as well as estimates of the forest land that would be required to provide for energy consumption and sequester sufficient carbon to compensate for carbon emissions. The common unit into which other land areas are converted is a "global hectare" with a productivity equal to the average productivity of the roughly 11.4 billion bioproductive hectares in the world (Monfreda,Wackernagel, and Deumling 2004).

One of the heuristic benefits of presenting the global burden of urban areas in terms of ecological footprints is that it serves to emphasize the fact that urban settlements are heavily dependent on biophysical processes taking place elsewhere, and provides a common "currency" rooted in biophysical rather than economic productivity. They also help to illustrate how misleading it can be to view different urban settlements (or countries) as occupying different positions on a common development trajectory,

4. *Encyclopedia of Biodiversity*, ed. S. A. Levin (San Diego: Academic Press, 2001), s.v. "ecological footprint, concept of" (by W. E. Rees).

given the limited ecological "space" available. In short, imperfect though they may be, ecological footprints provide a useful counterpoint to conventional economic accounts.

Ecological footprints are meant to measure outcomes, in the sense that they provide an accounting of services appropriated. From the perspective of spatial externalities, they are better interpreted as pressure or stress indicators. Environmental and ecological externalities are extremely difficult to measure, but one would expect them to be more closely associated with ecological appropriation, as measured by the ecological footprint, than with the economic value of consumption/production as measured in national income accounts. To some degree, global markets also globalize the side effects of economic activity (Mol 2001). Some researchers have even interpreted the ecological footprint as an attempt to measure these environmental externalities (Nijkamp, Rossi, and Vindigni 2004). An ecological footprint does not, however, even attempt to measure the extent to which environmental burdens remain external to market transactions and are incurred without any private negotiation or public regulation. Thus, while a larger ecological footprint is likely to be associated with greater environmental externalities, the two are both empirically and conceptually distinct.

Ecological footprints are increasingly being calculated for nations rather than urban settlements. The availability of national data allows for more extensive statistical analysis. Ecological footprint estimates have, for example, been used as a measure of environmental impact in a framework that treats the IPAT equation (above) as the basis for examining statistical relationships rather than as an accounting identity (York, Rosa, and Dietz 2003). Not surprisingly, population and GDP were found to be highly significant in all of the models tested. Latitude was also found to be significant, a result interpreted as reflecting the important role climate can play in influencing consumption patterns and environmental impacts. Somewhat more surprising, the percentage of population that is urban was also found to be highly significant in models where it was included, suggesting that urbanization either directly (for example, through impacts associated with the physical features of urban settlements) or indirectly (for example, through impacts associated with lifestyles that urban residents are more inclined to adopt) increases the size of a country's ecological footprint.

Ecological footprint analysis is sometimes presented as a more comprehensive measure of environmental impact than local or regional measures because global impacts are included. This can be taken to imply that environmental impacts increase monotonically with economic growth, and that the different relationships associated with local environmental health hazards (which tend to be at their worst in low-income settings) or city-regional impacts (which tend to be at their worst in large, industrialized, and often middle-income cities) reflect the partial nature of their indicators. Thus, for example, it has been argued that the rise and fall of the environmental Kuznet's curve reflects the omission of global impacts, whose inclusion would transform the curve into something more S-shaped (see York, Rosa, and Dietz 2003, fig. 1). This is misleading, however, as the form of the relationship also depends on how environmental burdens are measured. It is perfectly conceivable that a measure based on human health impacts would still display the aggregate environmental burden declining with economic growth (see, for example, Holdren and Smith 2000, fig. 3.10), while a measure based on economic value might rise and then fall, and a measure based on appropriated bio-physical productivity might rise monotonically.

It should be possible to combine insights from different scales, but this requires more than simply extending analysis from one scale to the others. Ecological footprint analysis is not a useful tool for examining local environmental burdens, just as burden-of-disease analysis is not a useful tool for examining global environmental burdens; yet both provide information relevant to any multi-scaled assessment of urban environmental burdens.

6. Scaling urban environmental policy agendas

An optimist looking at the environmental history of most affluent cities sees: a centuries-old and highly successful sanitary revolution (addressing environmental health burdens in and around people's homes); a more recent and partially successful pollution revolution (addressing pollution, waste, and resource burdens in the urban-region sphere); and perhaps the beginnings of a sustainability revolution (addressing the global environmental burdens of urban consumption patterns). A pessimist, looking at the same history, sees the progressive displacement of environmental burdens from local to regional to global scales.

There is some truth to both of these views. On the one hand, past urban sanitary reforms, pollution management, and efficiency improvements do illustrate the potential for quite radical and effective responses to severe environmental burdens. On the other hand, the tendency to shift towards larger-scale and more-delayed burdens is a real concern, particularly if it going to require a global crisis to invoke a meaningful response.

Looking across the wide range of urban settlements around the world, there are also other concerns. Economic success is very unequally distributed, and environmental burdens tend to accentuate these inequalities. The environmental burdens of poverty tend to be localized, while the environmental burdens of affluence affect a larger public. Some of the most deprived groups are also the most likely to face multiple burdens: they are more vulnerable to the global threats driven by affluence such as climate change, are more exposed to problems of regional pollution and resource abuse associated with urban industrialization, and live in neighborhoods where sanitation is poor, water is difficult to access, and smoky fuels are used.

Also, while a great deal of attention is paid to the globalization of environmental burdens, for low-income groups the localization of environmental burdens is also a concern. Water and sanitation problems, for example, were once associated with epidemics that threatened all urban residents, and even the inhabitants of other cities and towns. This helped to inspire a social movement, and motivated municipalities and national governments to drive sanitary reform. Endemic diseases, largely restricted to low-income neighborhoods, do not provide the same public motivation. This may help to explain why the conventional top-down approaches to water and sanitation improvement no longer inspire, and why even relatively successful locally driven initiatives rarely receive much attention internationally.

More generally, the multi-scalar character of urban environmental burdens is itself a challenge for developing effective urban environmental agendas. International and inter-urban variation suggests that in different locations environmental burdens at different scales need to be prioritized. Ideally, priorities should be adapted to reflect the state of local environmental health conditions, the quality of

environmental relations with the surrounding region, and the size of a settlement's ecological footprint. Generally, this would justify a greater focus on environmental health issues in low-income settlements, and a greater focus on ecological footprints in high-income settlements.

There is also a relationship between the scale of the environmental burdens and the appropriate roles of different levels of government. Some governance failures can be traced to a mismatch between the scale of the problem and the scale at which the response has been articulated. Local governance should not be expected to reduce carbon emissions voluntarily, although it can be a very appropriate level for driving local water and sanitation improvements. Global governance, on the other hand, is clearly needed to help develop institutional mechanisms to reduce contributions to global climate change, but is inappropriate to developing institutional mechanisms for managing local water and sanitation systems. On the other hand, reducing local environmental burdens often requires support (or at least the absence of opposition) from global processes and institutions, while responses to global burdens often need to be rooted in local agency (Wilbanks and Kates 1999).

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Extra-urban impacts of urban activities such as ecological disruption and resource depletion in a cityâ€™s hinterland, and emissions of acid precursors and greenhouse gases. Regional or global environmental burdens that arise from activities outside a cityâ€™s boundaries, but which will affect people living in the city. It does not encompass: Problems in what are sometimes termed the â€˜socialâ€™, â€˜economicâ€™ or â€˜culturalâ€™ environment. Natural hazards that are not caused or made worse by urban activity. The environmental impacts of urban activities that are of no concern to humans, either now or in the