Environmental Science

AIMS Environmental Science, 3(1): 133-139.
DOI: 10.3934/environsci.2016.1.133
Received 8 February 2016,
Accepted 6 March 2016,
Published 9 March 2016

http://www.aimspress.com/journal/environmental

Editorial

Urban greening for low carbon cities—introduction to the special issue

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Abstract: As a measure to counteract the effects of urban sprawl, with the continued growth of cities worldwide, different modes of urban greening are being increasingly recognized. This special issue addresses current developments in the transition to low carbon cities employing a variety of urban greening techniques. The special issue consists of 10 papers, including four review papers on the topics of biophilic architecture; environmental versus marketable aesthetics; urban agriculture; and the rationale for mainstreaming. It also contains several original research articles, some (about half of the special issue) presenting case studies, as for green redevelopment in Trenton, USA; facade greening in Genoa, Italy; climatic effects (on air temperature) in Rosario, Argentina; a modeling study for Melbourne, Australia; and another Australian case study on the greening and "un"greening of Adelaide. In addition to a broadly scoped paper that examines American stormwater management, the special issue also contains an editorial on technologies for wastewater treatment. Together, these papers constitute a contribution to recognize the importance of retaining greenery in cities chiefly, although not solely, as a countermeasure to urban sprawl and its environmental impacts. Urban greening here represents a cost-effective (soft) approach that is an effective tool as part of sustainable development.

Keywords: biophilic architecture; environmentalism; urban agriculture; urban greening mainstreaming; green redevelopment; facade greening; climatic effects; modeling; greening and "un"greening

Recent attention has turned to the improvement of environmental conditions in cities. As countermeasures in the face of urban sprawl and the effects of urbanization, urban greening techniques possess much promise. Unsurprisingly, various recent efforts in the form of individual articles as well as special issues, such as Sustainable Urban Development (2014) [1] and Towards True Smart and Green Cities? (2015) [2] in an MDPI journal, *Sustainability*, have also adopted this approach to cities. This introduction to the *AIMS Environmental Science* journal special issue on Urban Greening and Low Carbon Cities combines approaches taken in past conferences (e.g., Low Carbon Cities, Porto, Portugal,

2009) [3] and special issues (e.g., Green Cities, 1996 was one of the first special issues published by the journal *Cities*) [4]. Also from Elsevier, the *Journal of Ecological Indicators* is currently planning a special issue: From Urban Sprawl to Compact Green Cities – Indicators for Multi-Scale and Multi-Dimensional Analysis [5]. The ASCE *Journal of Urban Planning and Development* (from the American Society of Civil Engineers) also recently published a special issue on Green Infrastructure for Urban Sustainability, linking urban greening to long-term environmental sustainability [6].

In addition, already published case studies, such as those addressing low carbon urban transitioning in Melbourne, Victoria in Australia [7], provide international examples. Another example is from African cities, where limited industrialization has circumscribed urban greening and, therefore, its potential to resolve longstanding development-environmental issues among other problems [8]. By early 2014, for example, there were only 50 green buildings located mainly in the cities of Johannesburg and Pretoria in South Africa, even though it (South Africa) is considered to be a leader, outside of Sub-Saharan Africa, in greening and sustainable urban development [9]. Elsewhere, low carbon planning case studies from Copenhagen and Kyoto [10] address "urban green cosmopolitization" and urban visions spurred by architects and engineers. In the Japanese city of Kawasaki [11], low carbon measures were assessed, including rooftop greening, but solar insulation cover films were found to be most effective in decreasing CO_2 emissions. However, various local conditions are known to have an impact on such measures, such as land and building use as well as climate. In India, where CO_2 emissions are similar to China, but lower than comparable American cities [12], greening (in "green" cities, such as Bareilly and Allahabad) was found to be an effective way to reduce the urban heat island effect and cooling degree days.

Urban greening can take on different forms, incorporating facade greening and rooftop gardens as part of green architecture; forested areas and parks; as well as allotments and urban farming. Vacant lots can provide ecosystem services if they contain trees, as for instance in Roanoke, Virginia, USA [13], where vacant land was discovered to comprise 210,000 trees and have a tree cover of 30.6%. These trees were found to store some 97,500 t of carbon and remove approximately 2090 t of carbon and 83 t of other air pollutants annually. This is considered to be higher in comparison to other land uses in the city. This is not a stand-alone example, and the Oak Valley resort in Wonju, Korea [14], for instance, was able to offset its total carbon emissions (associated with touristic consumption for transportation, electricity, and heating) by 79.3% in 2006 due to the (temperate secondary) forest where this ski and golf resort is situated.

So, trees (especially aged or old-growth forests) with a dense canopy (high leaf area index or LAI) are capable of providing many ecosystem services in cities, including carbon storage, shading, and cooling effects, and are thought to improve urban climate [15]. In the Mediterranean climate, for instance, intensive green roofs of a substrate depth of at least 40 cm is required to grow olive trees [16]. The substrate depth is normally less than that (between 7.5 and 15 cm [17]) for extensive green roofs. In Baltimore, as a further case for the use of trees in urban greening, when trees were attacked by the gypsy moth (*Lymantria dispar* L.) in the 1860s, the outbreak resulted in costs incurred in terms of reduced pollution uptake and human health (medical treatment) in addition to an increase in carbon emissions [18]. Although people of different ages interact with an urban woodland differently [19], meanings attributed to them have included relaxation, peacefulness, seasonal change, scenery, and education, some of these connected to emotional wellbeing.

Trees should be incorporated wherever possible in the urban environment, as their function is evidently important for environmental (and human) health and the wellbeing of urbanscapes (and the people that occupy them). This is problematic in some areas, such as many Chinese cities, including Changchun, where a gradient between suburban into urban areas conveys a decreasing LAI as well as

canopy density and basal area of urban forests [20]. Other recent attention has been given to China [21], focusing on low carbon, sustainable development, including the address of urban forestry.

A combined urban greening and low carbon cities approach is adopted here based on the need to use (soft) environmental approaches to reduce carbon emissions in urban areas, where increasingly more people dwell, yet less natural vegetation remains to counteract harmful anthropogenic effects. The combination is ultimately attractive also because urban greening has a reversing effect (in the way that environmental restoration does) of undoing the environmental impacts that humanity has inflicted on natural landscapes in urban areas.

The term "urban greening" was coined by the German-born architect Steffen Lehmann, as conveyed in his Cities of the Future talk presented in Australia [22]. He is an inspirational speaker, having reached many audiences around the world through his talks as well as books, expressing his enthusiasm for low carbon cities and greener, sustainable cities [23,24]. People like him are driving global social change, in the face of climate change, in order to improve the human-environment fit in cities.

Books by other authors have also stimulated much thought and activity in this area. The Springer eBook *The Economy of Green Cities* (2013) [25] focused on an economic approach to urbanization (as the "green urban economy"), while also recognizing the importance of holistic approaches. Cities are multifaceted and, as such, require a multivariate approach that resembles their intricate nature. When considering economy, parameters other than industry and the workforce (employment) should be considered, and the cost of living is relevant (encompassing housing, transport, healthcare, education, insurance, etc.). In this way, urban greening is not just about building and infrastructural costs, but also those of healthcare and wellbeing, job creation, climatic impacts, wildlife and biodiversity, wastewater, and so forth. For example, urban greening applied to low-income, marginalized communities in Bangkok, Thailand, and Sri Lanka [26], including urban agriculture, effectively improved cross-scale linkages (as between residents and local authorities) and lay down a foundation from which to build initiatives based on sustainable development as well as city-to-city learning.

This suggests that urban greening is an important base for sustainable development. This approach was also adopted by a report on *Greening EU Cities* (2010) [27] that acknowledged the various interconnected parts working in cities, such as energy, transport, waste, water, and buildings and their (similar) challenges in Europe. European policy has supported sustainable development, including the encouragement of brownfield regeneration and the creation of greenspace (referred to as "brownfield regenerated greenspace") [28]. Such brownfield green initiatives, however, are costly and for this reason are difficult to regenerate simply as greenspace, especially given the competition for brownfield sites in many large cities around the world. Nevertheless, contemporary approaches are increasingly encapsulated by land-use planning and management [29] that acknowledge urban forestry as well as green building (e.g., Leadership in Energy and Environmental Design or LEED) and green infrastructure.

It is hoped that this special issue continues to shed light on how best to shape the cities of the future in various ways and from different perspectives. The authors of the papers contained in this special issue address case studies from around the world, including India, Australia, Italy, and more countries represented either in detail (as case studies) or more generally to examine and direct the status of urban greening. They encompass a variety of approaches to urban greening, such as green infrastructure, green roofs, green facades, and urban agriculture. While some of these studies have been interested in measuring the effects or impacts (as of carbon sequestration, summer cooling, air temperature, perceptions), others are more critical (examining rationale, policy, movements) and/ or based on applications of urban greening (where they have been successful, unsuccessful, or are needed).

Summary of papers:

(1) Indian green infrastructure is examined for its potential as a sustainable approach to urban expansion [30]. Investments in green infrastructure from a connected (states) scope allow for a combined plan for economic development and ecological sustainability.

(2) The paper on greening and "un"greening of Adelaide, South Australia presents planning contradictions [31]. It addresses conflict arising from, for instance, maintaining biodiversity versus keeping people away from bushfire risk areas through low-density urban sprawl. The paper also elaborates on new "greening" initiatives, including green roofs, water harvesting, agriculture, and low carbon living systems.

(3) A simulation of the summer cooling potential of urban vegetation found that average seasonal summer temperatures were reduced 0.5–2 ℃ in the central business district (CBD) of Melbourne, Australia [32], but only in the presence of planted parklands and vegetated suburbs that would effectively reduce the number of hot days.

(4) Urban climate was investigated from a local scale using digital sensors to measure actual temperatures at eight sites in Rosario, Argentina [33]. The findings convey that air temperature in the city core (where there is no vegetation) was higher than at vegetated sites, both in the day and at night, with the exception of where street trees were located in the central core site.

(5) The review paper on urban agriculture acknowledges and promotes the opportunities offered by urban food production, including enhanced food security [34]. It adopts a global perspective of urban agriculture, seen as a mitigation-adaptation tool amidst a growing world population. Urban agriculture has potential as a carbon capture and storage system (a soft-engineering strategy) and a land-based solution to counteract the impacts of urbanization as well as establish a (functional) continuum between cities and the countryside. Urban greening uses considered vary from forests and parks to green roofs and gardens. It can be extended to encompass traditionally rural services (in cities) and alleviate pressing social problems, such as world hunger and unemployment. It also contributes towards community-building in urban areas and reduces stress to farmland. Urban agriculture has the same potential as non-agricultural applications of urban greening, as it provides a pollution buffer and improves (environmental and human) health and wellbeing. It presents an integrated (social-ecological) approach.

(6) A critique of American stormwater management is provided [35] based on low impact development (LID) techniques adopted by municipal governments using a permit system. A lack of policy transfer from the federal to state and local governments prevented the promotion of a green approach that was initiated at the national (federal) level by the Environmental Protection Agency (EPA).

(7) Facade greening of an office building allowed for the use of sociological survey administered to local residents and employees in order to assess perceptions of green architecture [36].

(8) The need for green redevelopment was established using geographic information systems (GIS) based on smart-phone baseline data derived from a vacant property survey [37].

(9) Another review paper [38] examines the multitude of greening options (trees, gardens, bioswales, green walls and roofs, brownfield redevelopment, parks, etc.) in order to question the assumption that urban greening has positive environmental impacts. The problem posed is that green aesthetics and environmental sustainability are not always mutually inclusive, and the former can often dominate planning agendas. Techno-fixes cannot operate in isolation, and a social dimension to change is needed, as with the co-production of knowledge. The

review paper on biophilic architecture [39] emphasizes the human-nature link and connected health (both physiological as well as psychological). It also recognizes the multiple benefits (socioeconomic as well as environmental) of biophilic architecture.

Acknowledgments

I am grateful to the authors and those involved in the publication process at *AIMS Environmental Science*.

Conflict of Interest

There is no conflict of interest.

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