Title

Can urban greenspace combat climate change?: towards a subtropical cities research agenda.

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ABSTRACT

It now seems likely that we are locked into irreversible climate change - at least for the next century. A noticeable effect has been a pole-wards expansion of the tropics and by extension, an increase in the number of subtropical cities. The consequences of climate change for subtropical cities include higher temperatures, increased flooding and more severe storms. This article explores how urban greening might help subtropical cities adapt to climate change, using a model to conceptualise the factors shaping the efficacy of urban greening as an adaptive strategy. It discusses current research and maps out issues for future consideration. They include the potential problems facing planners who might employ greenspace to combat climate change in subtropical cities.

Keywords

Urban parks, greenspace, climate change, adaptation, subtropical cities

Introduction

How best to adapt our cities to the looming threats of anthropogenic (human-caused) climate change is one of the greatest challenges facing contemporary urban and environmental planning (Campbell, 2006). The most recent warnings from some scientists suggest not only that we already locked into unavoidable climate change, but that the situation could be worse than expected (Kintisch, 2009). Over the coming decades, our cities likely face an array of associated problems, including: rising temperatures, water shortages, food scarcity, and increased storminess - with concomitant flooding, wind-damage and coastal erosion (Allen Consulting Group, 2005, Australian Greenhouse Office, 2006, 2008, Frumkin et al., 2008, Gleeson, 2007, Ryan, 2008, Johnstone, 2008). We have already seen for example, how the crippling heatwaves of 2009, which ravaged Melbourne and Victoria, caused many deaths, catastrophic property damage and severely disrupted urban infrastructure. Railway lines buckled in 46°C degree heat and some dams and reservoirs were contaminated with bushfire ash (Munoz, 2009, Wotherspoon, 2009).

Governments at all levels have recently scrambled to implement mitigation and adaptation measures such as geosequestering carbon, expanding renewable energy, promoting compact cities, building new water infrastructure, preparing evacuation plans, preventing development of flood-prone land, installing flood barriers, reinforcing coastlines, and potentially abandoning some settlements (Brown and Southworth, 2008, Bulkeley, 2006, Byrne et al., 2009, CSIRO, 2007, Ruth, 2006). Yet many of these options are expensive, have long time lags and ultimately are politically unattractive (Burton et al., 2002, Giddens, 2009, Medd and Marvin, 2005). Urban greening could offer a cost-effective, environmentally benign and politically acceptable solution to many of these problems, but its potential as an adaptive tool is yet to be fully evaluated.

Unfortunately we currently lack knowledge about the overall biophysical capabilities of urban greenspace (e.g. the ability of different types of vegetation to sequester carbon or the area required to mitigate flooding) and the potential socio-political drivers and hurdles to 're-greening' cities (i.e. how residents and urban land managers might respond to efforts to increase parkland vegetation densities or install green roofs on public buildings). Only a few researchers have attempted to measure the social and environmental costs and benefits of increasing urban greenspace coverage in the context of climate change adaptation. The few existing studies have concerned cities overseas - mostly in temperate or Mediterranean climes (Gill et al., 2007, Jo, 2002, Jo and McPherson, 2001, Jo and McPherson, 1995, McPherson, 1998). The project presented here aims to fill some of these important knowledge gaps and to advance a research agenda on the capacity of urban greenspace to adapt Australasian cities, subtropical ones in particular, to climate change.

This account begins by profiling the urban greenspace and climate change adaptation literature. Next, a model is proposed to help us better conceptualise the various factors that likely determine the efficacy of urban greenspace as an adaptive strategy. Then an example of current research attempting to address some of these issues within Chinese and Australian subtropical cities is discussed as a work in progress. Finally, the article lays out a research agenda for exploring some of the potential costs and benefits of using urban greenspace to combat climate change and suggests fruitful directions for further investigation.

The benefits of urban greening

Urban greenspace could potentially insulate our cities against some of the ravages of climate change. For instance, it provides a range of 'nature's services' benefits that can combat various anticipated global warming impacts through: regulating ambient temperatures, filtering dust, sequestering carbon, attenuating storm-water, mitigating flooding, lowering energy consumption within buildings, lessening wind-speeds, and preserving biodiversity

(Barradas, 1991, Fernández-Juricic, 2000, Gill et al., 2007, Jim and Liu, 2001, Jo, 2002, Jo and McPherson, 1995, Jonsson, 2004, Lin et al., 2005, Longcore et al., 2004, Wolch, 2007, Yang et al., 2007, Yu and Hien, 2006).

However, we also know that some residents perceive urban greenspace as a threat to their personal safety or property (Fletcher, 1983, Gobster, 1998, Luymes and Tamminga, 1995, Westover, 1985, Burgess et al., 1988). For instance, providing more parks and trees in cities means more wildlife - and potentially more trouble for private and public property owners (i.e. sap on cars, undermined foundations of houses, increased fire risk, nuisance noise, downed powerlines, damaged roofs, unpleasant odours and even an increased risk of animal attack on passers-by (e.g. swooping magpies) (Chipman et al., 2008, DeStefano and DeGraaf, 2003, Jones and Thomas, 1999, Messmer, 2009, San Julian, 1987, Schulz and Skonhoft, 2008, Seymour et al., 2006, Treves et al., 2006). Clearly the argument that city dwellers can benefit from contact with greenspace merits closer attention. Over the past three decades some researchers have begun to scrutinise this assertion; their findings suggest that planners should pay more heed to greenspace benefits.

Roger Ulrich and his collaborators for example, have found that greenspace provides relief from stressful urban environments (Ulrich and Addoms, 1981, Ulrich et al., 1990, Ulrich et al., 1991). Access to urban nature has been shown to allay anxiety and promote recovery from injury (Burls, 2007, de Vries et al., 2003, Kaplan, 2001, Kleiber et al., 2002, Maller et al., 2005, Orsega-Smith et al., 2004, Ulrich, 1984). Greenspace can also encourage more active lifestyles, cultivate a general sense of wellbeing and foster childhood learning and motor skills development (Bedimo-Rung et al., 2005, Frank and Engelke, 2001, Gearin and Kahle, 2006, Gobster, 2005, Heynen, 2006, Kuo, 2001). People who live near parks, nature reserves and other kinds of greenspace typically enjoy higher property values and improved conviviality (Crewe, 2001, Crompton, 2001, Crompton, 2004, Mitchell, 1995,

Nicholls and Crompton, 2005, Nicholls and Crompton, 2007). These studies collectively demonstrate that parks and other urban nature spaces could potentially allay many of the anticipated problems of climate change. But could planners use greenspace as an effective climate-change intervention in Australasian cities, especially those in humid subtropical climates?

Efficacy of greenspace interventions for subtropical cities

Generally defined, the term 'subtropical' refers to those areas outside the tropics, bounded by the tropic of Cancer and the Tropic of Capricorn. More specifically, subtropical cities fall within those areas having a warm, humid, and wet summertime climate and a cooler, drier winter climate (Lugo et al., 1999, Smith, 2008). Well known examples include Curitiba in Brazil, Durban in South Africa, Dallas in the United States, Hong Kong in China and Brisbane in Australia.

The subtropical milieu poses a number of challenges for adapting cities to climate change. Summers are typically hot and humid; daytime temperatures are usually in the mid to high 30s °C; night-time in the mid 20s °C. Powerful episodic thunder storms and torrential rain are common; breezes fluctuate in intensity. On the hottest days, urban environments can be stifling. Summertime cyclonic weather brings gale force winds and driving rain. Winter, although cooler, drier and less humid, can still witness intense storm events and in some subtropical cities even snow.

Climate change is expected to bring higher-intensity episodic rainfall (and flooding), hotter night-time temperatures, more extreme cyclonic weather (with higher wind-speeds), higher rates of evaporation, an increase in disease transmission through bacterial and insect-borne diseases and extirpation of some local species (Intergovernmental Panel on Climate Change, 2007, Zhang, 2007). Heat-island effects in subtropical cities are expected to amplify temperatures (Campbell-Lendrum and Corvalán, 2007, Lin et al., 2005, McMichael et al.,

2006, Tibbetts, 2007, Zhao et al., 2006). And the high growth-rates expected for many subtropical cities in coming decades will bring with them increases in airborne pollutants and paved-surface areas, with associated higher rates of respiratory disease and flooding (Harlan et al., 2008, Yang, 2008).

Greenspace could offer relief from many of these problems, but we do not yet know how much land area and what kind of plant species mixes will be effective in subtropical environments to achieve the necessary sorts of countermeasures (i.e. reducing flooding, cooling ambient temperatures, intercepting stormwater, attenuating wind, sequestering pollution, and preserving biodiversity). Nor do we know if increased levels of greenspace will be accompanied by increases in potential disease vectors like mosquitoes. And we have yet to ascertain how residents and park users might respond to increased vegetation densities and more urban wildlife. Finally, we have yet to establish if land managers and decision-makers will be prepared to trade-off the increased benefits of additional greenspace against some of the potential costs (e.g. reduced developable areas, increased insect numbers, maintenance burdens and storm damage). While many of these issues have been addressed in isolation, what now we require is integrated research that aims to understand the combined effects of these factors, and to quantify their costs and benefits for urban land managers, decision-makers and residents alike.

Conceptual model

The capacity for urban greenspace to mitigate climate change impacts can be conceptualised as a function of four broad classes of factors: (1) the biophysical characteristics of the built environment; (2) the philosophy of planning which underpins land use regulation and management; (3) structures of governance which shape decision-making processes (e.g. opportunities for public involvement); and (4) residents' perceptions and use of parks, reserves and other kinds of greenspace (see Figure 1).

These factors do not operate in isolation; rather according to the conceptual model proposed here, they interact in complex ways, affecting the overall efficacy of greenspace as a climate change intervention. For example, the amount of land available for greenspace will directly affect the 'ecosystem service' benefits it provides (i.e. the amount of carbon that can be sequestered or degree of cooling that can be provided by a pocket park is obviously very limited when compared with a large regional park) (Emmanuel and Fernando, 2007, Huang et al., 2008, Peng et al., 2008). So too, the types of vegetation within an urban greenspace will limit its capacity to mitigate climate change impacts. For instance, lawn does not have the same type of stormwater interception capability as a rainforest canopy (Xiao and McPherson, 2002). Scale will therefore be an important determinant of the ability of greenspace to offset expected impacts (Heynen, 2003, Heynen, 2006, Heynen and Perkins, 2005). For these reasons, the interventions that can be achieved in a pocket park will unlikely have the same impact as those for neighbourhood or regional greenspaces, floodplains, transport and utility easements, or street tree planting schemes.

On the socio-political side, how residents perceive and use greenspace will likely influence the decision of land managers to either expand greenspace areas or seek alternative uses for existing greenspace. The ability of land managers to maintain greenspace is a function of governance structures and resource allocation. If greenspace is not seen as a priority, it is unlikely to be funded (Heynen, 2006, Heynen and Perkins, 2005). Similarly, past philosophies of planning will have already determined the amount of existing greenspace in built environments (Byrne et al., 2007, Byrne and Wolch, 2009). Our capacity to augment these areas will depend upon resources, political will, and residents' perceptions of costs and benefits, shaped by their own experiences of accessing and using parks and other forms of greenspace. We can see then, that using greenspace to adapt to climate change impacts is not simply a matter of planting a few more trees in public parks.

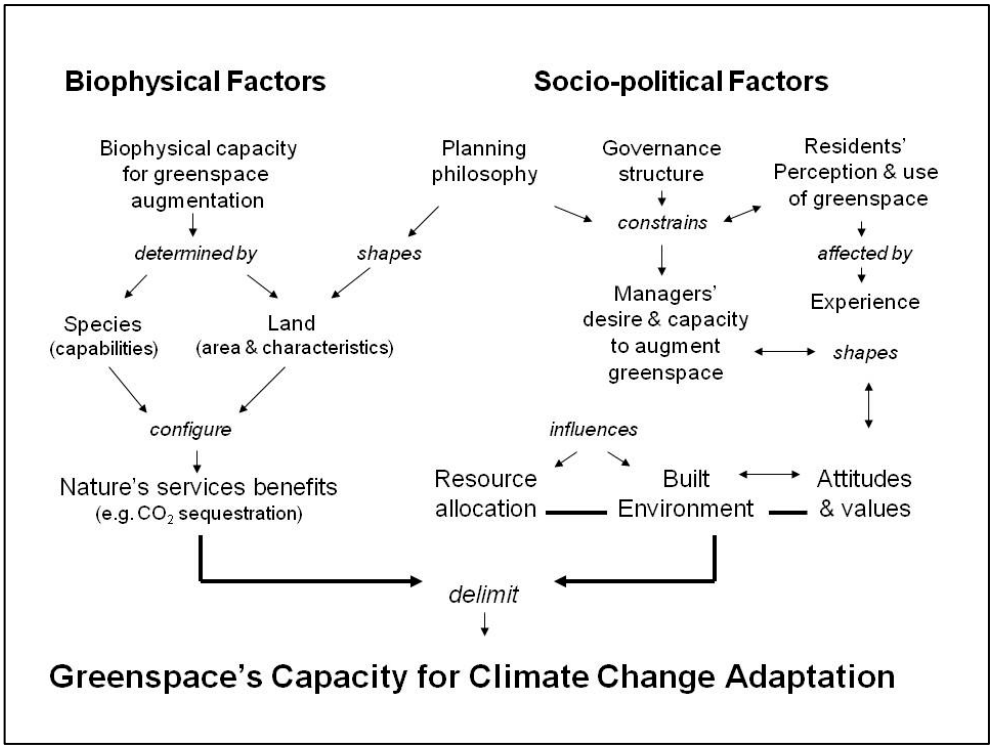

Figure 1: Conceptual model illustrating factors affecting the capacity of urban greenspace for climate change adaptation (source: authors)

New kinds of questions and new types of research

When it comes to measuring the costs and benefits of urban greenspace as a climate change intervention, what we need are new types of research projects that build interdisciplinary linkages between natural scientists (e.g. botanists, ecologist and biologists) and built environment specialists (e.g. planners, engineers, architects, sociologists and geographers). This research should also integrate new methods, and combinations of methods, for analysing built form, species compositions, socio-demographic information, and health data, to better understand which urban residents are potentially worst affected by climate change and where the greatest social, economic and environmental impacts will be felt. Then it will be necessary to test strategies for managing these impacts, through policy change, behavioural change, green infrastructure provision and institutional reform (e.g. Buckley, 2007, Baum et

al., 2009). For example, how will residents who have traditionally eschewed dense urban vegetation in favour of ornamental palm trees react to increasing urban greenspace coverage as a climate change response? Will they make trade-offs between perceived advantages such as cooler temperatures and less flooding and disadvantages such as perceived decline of personal safety or increases in nuisance wildlife? Moreover, which factors will influence their decision-making?

Although urban land managers are typically portrayed as having ambivalent attitudes towards urban greenspace, we actually know little about their views and opinions (Bright et al., 2002, Heynen and Lindsey, 2003, Xiao and McPherson, 2002, McPherson, 1992). International research suggests that urban managers might be aware of the many benefits that urban greenspace confers, but the realities of dwindling municipal budgets and increasing local government responsibilities oftentimes mean that development is poorly resourced and new plans are seldom implemented (Gobster, 2001, Heynen, 2006, Heynen and Perkins, 2005).

The emerging opportunities in Australia for urban greenspace to act as a sink for emissions in a nascent carbon market means that local governments cannot afford to ignore the potential revenue earnings and savings that could be generated by providing more parks, urban forests and vegetated riparian corridors to offset carbon emissions. Similar opportunities exist in other countries which are contemplating emissions trading schemes (e.g. the United Kingdom). How then might greenspace managers respond to these new opportunities? Will they perceive greenspace restoration as a legitimate adaptation strategy? What are their concerns if any, with such an approach? And how will the perceptions and attitudes of urban residents influence their decision-making and management approaches? For example, would local governments be prepared to trade-off maintenance costs of mowing lawns for the potential benefits of increasing vegetation cover in greenspaces?

A 2009 case on the Gold Coast illustrates the potentially vexatious nature of these matters. Against the backdrop of ambitious plans to achieve a city carbon neutral city by 2020, and the fiscal constraints imposed by the global financial crisis, the City Council released a report investigating the feasibility of closing some 'underutilised' playgrounds and revegetating them with native vegetation (Council's park maintenance costs topped $34 million for the 2008-09 financial year). Front page articles in the *Gold Coast Sun*, complete with photographs of gloomy-faced children posing in front of play equipment carried headlines such as: "fun police strike", "playtime is over" and parents angry at bid to axe parks" (see figure 2). The community backlash was palpable. Parents were incredulous that a city renowned for is balmy subtropical climate would turn its back on the outdoor play needs of its youngsters. And planners looking for innovative solutions to dwindling coffers and looming climate threats were labelled "fun-wrecking bureaucrats" (Elder, 2009a, 2009b, 2009c). What options exist then for navigating our way through these sorts of conundrums? Can we achieve increased vegetation density and still maintain functioning spaces for active recreation in subtropical cities? These are some of the questions being posed in a new comparative research taking place on the Gold Coast and in Hangzhou, China.

Figure 2. Newspaper coverage of Gold Coast greenspace plan

A Chinese and Australian comparative research project

New international research is attempting to quantify the costs and benefits associated with using greenspace as a climate change intervention. It seeks to evaluate strategies for deploying greenspace in two cities sharing a subtropical climate but with diverse built environments and very different governance structures. Set in Australia (Gold Coast) and China (Hangzhou), the research - which is currently in progress - aims to better understand how park users view climate change, whether they regard urban greenspace as an effective climate change intervention and the problems that might exist for environmental planners who want to increase vegetation densities within different types of park and public spaces (e.g. plazas, civic squares, railway easements, canal frontages and road reserves). The project is also seeking to elucidate the attitudes of land managers and decision-makers towards urban

re-greening and to establish their awareness of climate change impacts upon their respective cities.

Methods

The research relies upon an innovative combination of remote sensing, GIS modelling, park-user surveys, vegetation surveys, and in-depth interviews. Researchers are presently collecting vegetation data within different types of urban spaces using hand-held arc-pad GPS devices, and are inputting this data into a GIS extension called "CITYgreen" developed by the United States non-government organisation 'American Forests' (American Forests, undated), so as to ground-truth Normalised Distribution Vegetation Index (NDVI) data for these spaces. The vegetation data will allow CITYgreen to be further calibrated for cities outside the US, enhancing its utility for planners and land-managers.[1]

The first phase of the project in Hangzhou has been completed. It collected intercept data from park users in three different types of parks: (i) a civic square with little vegetation; (ii) a city park with a mix of vegetated and paved surfaces; and (iii) a new nature park developed between a rail easement and a canal. The third stage of the project, which is yet to begin, will collect interview information from park-managers and planners responsible for tacking climate change in the city. The vegetation information will then be analysed in conjunction with intercept survey data on the attitudes of park users towards different vegetation densities, and data from interviews with land-use managers and decision-makers. Although similar modelling has been undertaken before in the United States (Longcore et al., 2004), the software has not been widely used outside that country. The current project is expected to produce new species data for the model (from Australia and China) potentially generating innovative results, and offering new insights into greenspace management, grounded in the 'everyday' realities of greenspace planning and park use.

[1] Peng et al. (2008) recently applied CITYgreen to Nanjing, China with good results.

Expected results

The research is expected to greatly enhance existing knowledge about climate change impacts on the Gold Coast and Hangzhou, because recent studies have tended to be broad-brush and lack detailed analyses (Gill et al., 2007 is a notable exception). For example, the study moves beyond general land use categories to collect field data on several trial plots that are representative of existing urban greenspace in these cities. This move will help planners to determine specific species compositions that can be matched to carbon sequestering capabilities. The effectiveness of urban greenspace in mitigating expected impacts of climate change will be modelled using the CITYgreen software, and results will show the Australian dollar (AUD) / Chinese renminbi (RMB) value of the various nature's services functions that this greenspace is providing. It will also show the types of savings realisable if different types of public spaces were revegetated at different levels, assisting land managers in making some of the difficult decisions that lie ahead.

Results will also reveal park users' perceptions of greenspace values and their attitudes towards increasing the density of urban greenspace in their neighbourhoods. It is expected that the study will demonstrate the types of tradeoffs between perceived advantages and disadvantages that residents and land managers will make, and the criteria they use to do so. The research should reveal the conditions under which residents and land managers will be prepared to accept some of the perceived disadvantages associated with denser urban greenspace (e.g. storm damage, diminished personal safety, nuisance wildlife) in return for greenspace benefits such as carbon sequestration, stormwater attenuation, reduced temperatures, increased privacy, dust suppression and access to urban nature. Finally, the project will reveal if land managers would be more favourably disposed towards augmenting and restoring urban forests, parks, riparian corridors, greenways and other forms of

greenspace under conditions where citizen-opposition is minimised and nature's services returns are maximised.

These findings will assist planners in Australia and China to make better decisions about protecting existing greenspace and expanding greenspace coverage. Research using CITYgreen in other cities has definitively shown that planners can achieve real fiscal benefits by preserving urban greenspaces. But Longcore et al. (2004) found from their study of Los Angeles greenspace that CITYgreen has some limitations, as the parameters used by the model (e.g. stormwater retention, wildlife benefits, carbon sequestration) do not apply well to Mediterranean climates. Moreover, they also require some modification when applied outside the US (e.g. stormwater coefficients, soil types, species types, growth rates and carbon uptake). However, CITYgreen modelling for greenspace in Nanjing, China, by Peng et al. (2008, p. 180) suggests that these sorts of adjustments can be made, and do in fact return useful results for planners and land managers – especially in subtropical areas.

Specifically, Peng et al. found that urban forests in Nanjing provide total carbon sequestration and stormwater reduction values of 177 million RMB (AUD$ 29.5 million) – comprising a "total carbon storage capacity of …about 7.36105 t" and an "annual benefit of 1.346106 RMB". They also estimated stormwater benefits, assuming "a construction cost of 1RMB/m3, in constant 2001 prices"; the stormwater economic value "was calculated at 3.446106 RMB" (Peng et al., 2008, p. 181). But these studies lack two vital planning components if they are to be useful in helping planners figure out the costs and benefits of greenspace for climate change adaptation. First, they lack the ability to predict the likely increase in benefits if vegetation density in existing greenspace is increased or greenspace land-cover expanded. Second, they have not factored in the attitudes, values and perceptions of greenspace managers and residents. That is the purpose of the project reported here.

Conclusion

The challenges confronting land use planners in adapting cities to the anticipated impacts of climate change are considerable. Recent experience has shown that attempts to prohibit development on flood-prone land or rapidly deploy large-scale infrastructure like desalination plants are fraught with difficulty, can be politically unpalatable and, in many circumstances, are likely to be hotly contested in various courts (Byrne et al., 2009). Urban greening offers an environmentally benign and politically expedient means of adapting cities to climate change, but its potential costs and benefits to planners and residents are still poorly understood. Moreover, the relationship of greenspace and climate change has not been studied in subtropical cities, places that are set to expand as global warming takes hold.

This article has reviewed current research on the 'nature's services' and the social benefits of urban greenspaces. It has considered a vexing case of trading off costs and benefits on the Gold Coast, and has discussed the potential benefits for land-use planners and land managers of expanding greenspace coverage and increasing vegetation densities. The paper has argued that a more integrated research agenda is urgently needed, focusing upon action-oriented outcomes. Future research projects must demonstrate to planners, land managers, decision-makers and residents alike the various tradeoffs of 'going green', and enable them to determine if it is a worthwhile strategy in the face of an urgent need for climate change action.

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