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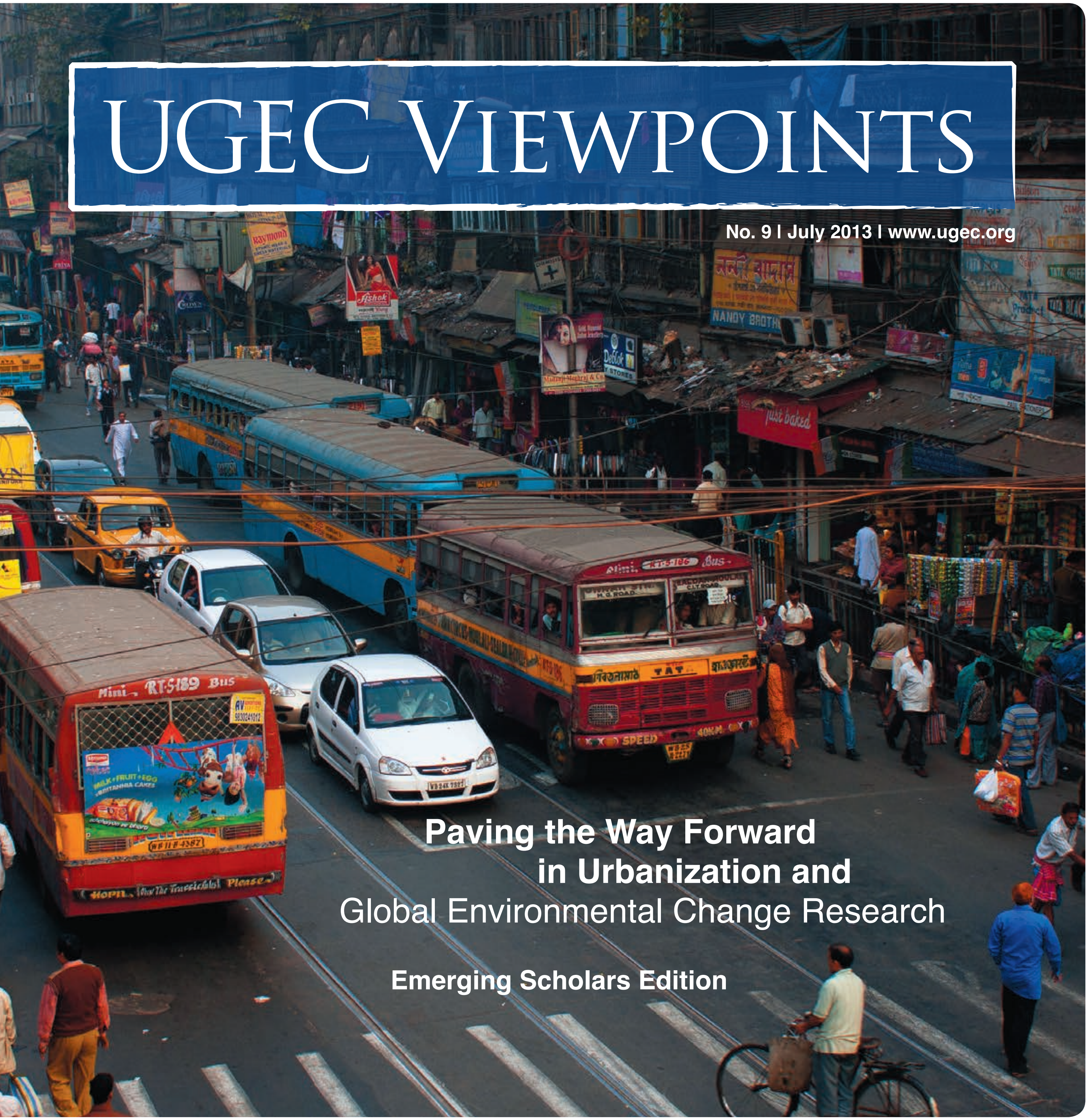

Paving the Way Forward in Urbanization and Global Environmental Change Research

Emerging Scholars Edition

IHDP
International Human Dimensions Programme on Global Environmental Change

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Editorial

Dear friends of the UGEC project,

I am delighted to share with you this ninth issue of *UGEC Viewpoints* — one of my favorite issues produced thus far! Over the years, the UGEC project has placed attention on creating capabilities among young scholars and practitioners offering opportunities for networking, collaboration and publication, and has organized several training workshops with other international organizations towards these efforts. The bi-annual *Viewpoints* publication has always been an avenue through which our colleagues working and doing research in the field of urbanization and global environmental change are able to showcase their expertise to the international community, and discuss key issues and gaps in knowledge critical for moving forward. This particular issue is no exception, but more so, highlights research from emerging scholars within the UGEC network. It seems most appropriate at this stage of the project to transition the focus of the *Viewpoints* towards our future scholars.

Recently, there have been many exciting developments and discussions with respect to the Global Change Research Programmes and Projects, which are currently transitioning into the new 'Future Earth' research framework for global sustainability. This is an exciting process in which UGEC has continually been engaged, and runs in parallel with the third stage of our project which is now heavily focused on synthesis. This mix of reflection and synthesis as well as looking towards the project's future and that of urban/environmental research has been quite an exciting endeavor — a process that will continue throughout the next few years and for which we are planning a number of activities, namely our 2nd International UGEC Conference, 'Urban Transitions and Transformations: Science, Synthesis and Policy' to take place in Taipei, Taiwan, November 6-8, 2014.

One of the key components identified for the success of 'Future Earth' is to a focus on including and building the capacity of young scholars and practitioners. This is certainly important for UGEC moving forward, particularly in the context of better addressing global environmental issues in urban areas. As such, we will continue our efforts to expand the opportunities for the engagement of young and emerging scholars in our future activities and publications, particularly through future issues of the *Viewpoints*. That said, I would like to introduce to you the authors of this ninth issue who are graduate and post-doctoral students, and young faculty representing a diversity of regions and research interests. Herein, you will read articles highlighting urban adaptation responses and pathways for developing adaptation planning approaches and agendas (H. Leck, and A. Kingsborough); urbanization impacts on wetland areas and potential responses (Y. Cai & X. Wang, and N. Bateganya et al.); the threat of urban sprawl to biodiversity and the importance of sustaining urban ecosystem services (M. Mandemaker et al., and N. Soonsawad); sustainable urban growth and transformation in arid Egypt (A. Hassan); disaster risk and green investment in cities (T. Wakiyama & J. Jupesta); and three insightful articles that investigate the Urban Heat Island effect including how to better understand it, its associated challenges and potential strategies for resilience (J. Vargo, R. Sharma & P. K. Joshi, and A. Trundle et al.).

I hope that you enjoy this issue as much as I've enjoyed putting it together. I must thank the authors for their contributions and as always, the readers and wider UGEC community for your continued engagement and interest in the project. I hope that many of you will be a part of our next year's conference, which you will be hearing much more about in the very near future — so please stay tuned!

Enjoy the read!

Corrie Griffith
UGEC Executive Officer

Table of Contents

eThekwini (formerly known as Durban), South Africa

The Role of Local Politicians and Political Realities in Shaping Urban Climate Change Agendas: The Case of eThekwini Municipality

Hayley Leck

The growing international consensus about the urgency of tackling climate change, or more broadly global environmental change (GEC), has been accompanied by a burgeoning literature on the dynamic complexities of multi-scalar climate change governance and challenges to policy implementation. The pivotal role of municipalities or local authorities as key locales for climate action is now well established in this literature, with considerable research interest stemming from the widespread recognition that much climate change adaptation (CCA) and some mitigation (CCM) actions are ultimately implemented at local scales.

While many municipalities, particularly those that are well-resourced and networked, have demonstrated leadership and innovation through starting to engage meaningfully with climate change in recent decades, actions have been somewhat ad hoc and weakly embedded in broader municipal systems and operations (Aylett, 2013; Bulkeley & Betsill, 2013; Leck & Simon, 2013). Further, municipal climate change agendas are still often considered in an apolitical manner, with limited recognition and deep understanding of the decisive role of intertwined politics, politicians and power in shaping them. This has especially been the case with traditional science-led technocratic approaches to CCA and CCM research and decision-making.

This article presents some key results from doctoral research that investigated climate change response strategies, specifically adaptation and the enablers and constraints thereto within eThekwini (formerly known as Durban) metropolitan municipality in KwaZulu-Natal province, South Africa. The main methods of data collection were interviews, focus groups and surveys. Key participants included government officials from various municipal departments and provincial bodies, local politicians, representatives from academic and non-governmental institutions, and local community members in diverse urban and rural communities. While the results revealed that inevitably there are a number of interlinked factors at play, the role of local politicians and politics emerged as key drivers shaping local strategies and capacities to respond to climate change. While the research focused on the city of Durban as a specific case study, many of the key findings apply more broadly in developing contexts and indeed cities that are well established in this regard.

Addressing climate change in Durban: progress and challenges

eThekwini is a major South African city that contributes significantly to the provincial and national economy as the largest port in Africa. The city has taken a climate change leadership role in Southern Africa through their proactive approach and prioritisation of adaptation from the outset with municipal, community and ecosystem-based adaptation plans underway. The strong Environmental Planning and Climate Protection Department (EPCPD) has driven these efforts. Together with their collaborators the EPCPD has developed several additional innovative measures, including an alternative cost benefit analysis tool that establishes benefits based on number of people reached and their impact on wellbeing, rather than relying on economic measures (Cartwright et al., 2013).

These developments notwithstanding, the city's climate agenda faces major constraints to implementation and broader institutionalisation. Notably, the need to meet urgent developmental and environmental rights creates intense competition for limited government resources. Indeed, alongside the quest to strengthen adaptive capacities to climate impacts at multiple scales, all South African cities and their political leaders face significant pressures to boost development and address service and infrastructural backlogs in the context of a highly unequal society. Furthermore, "local governments operate within a regulatory framework that reinforces the dualistic 'development-plus-impact assessment' paradigm" (Swilling, 2008, p. 103). Such dualistic outlooks and false environment – development divides create barriers to broader urban sustainability and climate action. Roberts (2008) confirms that this tension persists in Durban and has perhaps deepened as development challenges intensify in the city.

Local authorities' climate responses are nested in multi-scalar governmental and non-governmental influences that can have facilitative or constraining effects. Additionally, city governments work alongside a host of other urban actors such as local businesses in developing climate change agendas, often in partnership, but also sometimes in tension and with duplication of efforts (Broto & Bulkeley, 2013). Key additional factors influencing Durban's (and indeed many cities globally) climate change response capacities include inter alia inadequate organisational, technical, human and financial resources, weak inter- and intra-departmental communication, unclear roles and responsibilities, institutional silos, limited public support and a fragmented urban policy environment. In significant addition to these frequently cited aspects the majority of interviewees, including most municipal commentators, believed that political stability, dominant political agendas and the politicians driving them are key underlying determinants of broader local government functioning, and implementation and extent of the municipal climate agenda.

Urban politics and local politicians shaping local climate agendas

Local politicians have key decision-making powers over land use, development strategies, urban planning and other functions that strongly influence urban capacities for CCA. They also provide important links to provincial and national level politicians engaged in higher-level climate decision-making. Moreover, political will and leadership have a strong role to play in mobilizing society towards CCA and CCM. Thus, ongoing political support and influential involvement of key political actors in climate agendas at the local government scale is essential. Recognising this, certain political leaders, notably the previous and current eThekwini Mayors, have championed and enabled the local climate agenda. Significantly, the eThekwini Mayor led the signing of the Durban Adaptation Charter for Local Governments at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) 17 in December 2011. This notwithstanding, sustained and widespread political leadership and engagement is lacking. There are several discernible interconnected reasons for this as discussed in the following section.

Lingering skepticism, short-termism and conflicting economic priorities

Local actors expressed concern about lingering scepticism among political leaders regarding the reality of climate change and its potential impacts. As a government official noted,

> **"We are still up against the argument, is climate change really an issue? That still exists in this day and age, especially among our local political authorities. So you know there is a knock on effect of that further down the line at community levels… where this scepticism travels ".**

While politicians influence local communities in multiple ways conversely, politicians also act according to perceived public priorities and demands. Thus, addressing climate change must be understood in the context of bidirectional state and non-state actor relations and there is a need for continuous engagement, education and awareness raising across these spectrums.

Further, conflicting economic priorities and concerns about cost-effectiveness were identified as key drivers of politicians' actions that in turn limit CCA. The vast financial implications of not implementing CCA and CCM strategies are widely documented. However, a significant conundrum in Durban and cities in developing contexts more widely is that even if politicians and key decision-makers do recognise the importance of CCA, the extreme pressure to deliver housing, services (e.g., water provision) and other 'visible' results in a cost-effective manner to a large under-resourced population may outweigh this concern since adaptive technologies and infrastructure are often perceived as adding extra costs to limited budgets. The major concern is that such developments are missed opportunities that will inevitably require retrofitting, and rather than supporting household adaptation may actually increase vulnerabilities and adaptation costs.

Moreover, politicians are often in office for a single electoral period spanning only a few years. Consequently, political priorities and commitment are subject to change when new leaders come into power thereby impacting climate agendas, which require long-term planning horizons and investments. Certainly, an important insight from the study is that high turnovers, shifting party politics and short-termism in local government planning cycles restrict long-term trust and relationship building with politicians as well as efforts to secure political commitment to ongoing climate initiatives.

> Political will and leadership have a strong role to play in mobilizing society towards CCA and CCM. Thus, ongoing political support and influential involvement of key political actors in climate agendas at the local government scale is essential.

Such political leadership conundrums are widespread and pose major challenges to urban climate change agendas across diverse contexts.

Party politics and masked political agendas

Vote security is a further underlying political motif for delivering fast paced (often maladaptive) development, rather than adaptation investments that often have limited visible short-term political benefit. A city official articulated these aspects as follows:

> **"The political focus is shifting more and more. No politician puts money underground where you can't see it; that is where we need it though. They want that publicity; to be seen to be doing something, but our underground furniture is old and shaky and needs to be adapted".**

Reiterating these sentiments, Breetzke (2009, p. 5) explains that the provision of services and social facilities "represent the re-election 'ticket' for most political representatives". The phrases 'underground furniture' and investing 'money underground' refer to the installation and maintenance of critical infrastructure such as storm water drainage, sewerage, energy systems and foundations that are not readily 'visible' in the same way as housing and other developmental projects, yet are essential foundations for CCA and sustainable development. Maintenance as well as transformation of this infrastructure to suit changing climatic conditions is essential for adaptation, yet is often taken for granted (Bulkeley, 2010). Evidently, while the inter-linkages between CCA and development are clear, these are not yet firmly embedded in political agendas in eThekwini as in many cities worldwide. This notwithstanding, with increased awareness and visible impacts the costs of not adapting key municipal infrastructure, services and housing could also ultimately be a catalyst for action, particularly among politicians (Agrawala & Fankhauser, 2008).

Additionally, several commentators suspected that certain politicians who do show support for municipal climate plans are often driven by ulterior political motives and are not necessarily genuinely committed to supporting long-term implementation. For example, certain local government and non-government officials believed that high-level politicians who had hitherto disregarded the city's climate agenda used the hosting of COP 17 as an international marketing strategy and strategic political tool rather than an opportunity to meaningfully drive the climate agenda. Masked political agendas, negative perceptions and tense relations such as these can obstruct inter-governmental co-operation and collaboration necessary for driving the climate agenda and supporting urban sustainability goals.

eThekwini, South Africa

Conclusions and way forward

The snapshot of research findings presented above underlines the centrality of politics in mediating municipal climate agendas. Politicians are evidently key players that can facilitate or constrain responses to the municipal climate change action imperative. Politicians are faced with mounting urban stressors and conflicting priorities that are exacerbated by the increasingly urgent need to address climate change at the city scale. Several major obstacles to building climate resilience and adaptation in eThekwini and indeed cities globally are political. However, at the same time, local politicians and political parties are increasingly showing meaningful support for municipal climate agendas. More research is required to better understand how to build on this and support vast far-sighted leadership and commitment necessary for CCA and CCM. Local political arenas and the shadow and micro politics that underpin them are deeply complex. Thus, it is important not to generalize about party politics or the influence of politicians in diverse contexts. Nevertheless, a range of political sensitivities mediates all municipal climate agendas across the Global South and North. Irrespective of contextual specifics, all politicians are faced with a mosaic of urgent challenges that influence prioritization of climate action. These central aspects remain relatively underexplored both theoretically and empirically. Future research on municipal climate responses should explore further the pathways, mechanisms and motivations for involving powerful political actors and understanding political will for climate agendas. Dedicated municipal support structures are required and politicians need to be meaningfully engaged in municipal climate strategies from the outset in order for climate agendas to become deeply embedded in overarching municipal agendas and political priorities. This requires commitment not only from the politicians themselves but all local authorities and non-governmental stakeholders.

References

Agrawala, S., & Fankhauser, S. (2008). *Economic aspects of adaptation to climate change: Costs, benefits and policy instruments* (Executive Summary, May 2008). Paris: OECD.

Aylett, A. (2013). The socio-institutional dynamics of urban climate governance: a comparative analysis of innovation and change in Durban (KZN, South Africa) and Portland (OR, USA). *Urban Studies, 50*(7), 1386-1402.

Breetzke, K. (2009). *From conceptual frameworks to quantitative models: Spatial planning in the Durban Metropolitan Area, South Africa — The link to housing and infrastructure planning* (Report prepared for Revisiting Urban Planning: Global Report on Human Settlements 2009) UN-Habitat. Retrieved from: www.unhabitat.org/downloads/docs/GRHS2009CaseStudyChapter08Durban.pdf

Broto, V. C., & Bulkeley, H. (2013). A survey of urban climate change experiments in 100 cities. *Global Environmental Change, 23*, 92-102.

Bulkeley, H. (2010). Cities and governance. In P. Plunz & M. Paulo Sutto (Eds.), *Urban climate change crossroads* (pp. 29-38). Farnham, UK: Ashgate.

Bulkeley, H. A., & Betsill, M. (2013). Revisiting the urban politics of climate change. *Environmental Politics, 22*, 136-154.

Cartwright, A., Blignaut, J., De Wit, M., Goldberg, K., Mander, M., O'Donoghoue, S., & Roberts, D. (2013). Economics of climate change adaptation at the local scale under conditions of uncertainty and resource constraints: the case of Durban, South Africa. *Environment and Urbanization*, *25*(1), 139-156.

Leck, H., & Simon, D. (2013). Climate change demands that we work co-operatively: fostering multiscalar collaboration and co-operation for effective governance of climate change adaptation and mitigation. *Urban Studies*, *50*(6), 1221-1238.

Roberts, D. (2008). Thinking globally, acting locally-institutionalizing climate change at the local government level in Durban, South Africa. *Environment and Urbanization, 20*(2), 521-537.

Swilling, M. (2008). Local governance and the politics of sustainability. In M. Van Donk, M. Swilling, E.Pieterse, & S. Parnell (Eds.), *Consolidating developmental local government: Lessons from the South African Experience* (pp.77-108). Cape Town: UCT Press.

Big Ben at a distance, London, UK

Climate Change Risk Assessment and the Development of Adaptation Pathways

Ashley Kingsborough

The global climate is already changing, risks are increasing and impacts are being felt worldwide. There is a need for research that both increases understanding of the impacts of climate change and informs potential solutions (Lemos et al., 2012). There is also a need to significantly improve our use of existing climate information in decision making (Hewitt et al., 2012) and to develop decision making tools that may be utilised in systems with high degrees of uncertainty (Hallegatte, 2009).

Climate change adaptation planning and decision making is a significant challenge for local and national governments. A key component of this challenge is balancing the need for climate change adaptation activities with the need for existing economic, environmental and social development programmes.

This PhD research focuses on understanding the interactions between climate risk and vulnerability assessments, and the development of effective adaptation pathways as key components of climate change adaptation planning in cities. The objective is to better understand and demonstrate how climate change risk assessment can inform effective climate change adaptation planning.

The first step in this research was to review the existing approaches for adaptation planning and develop an alternative adaptation planning framework. This article includes a brief overview of adaptation approaches and highlights a number of critical adaptation planning challenges identified within the literature. A framework for adaptation planning developed as part of this research to address these critical challenges is then introduced.

London as a case study

Moving the research agenda for adaptation planning forward requires empirical demonstrations of how a theoretical framework can be utilised. A case study research approach will contribute to the understanding and overcoming of practical challenges related to climate change in urban systems.

London has been selected as the initial case study because it has a high degree of vulnerability to climate change impacts, as documented by numerous risk and vulnerability assessments.

London is at an advanced stage of adaptation planning and it has demonstrated a willingness to embrace innovative approaches (GLA, 2011).

The (ARCADIA) Adaptation and Resilience in Cities: Analysis and Decision making using Integrated Assessment project,[1] has developed an integrated assessment model that has been used to quantify climate risks in London. This integrated assessment model will be used in an exploratory manner in this research to quantitatively analyse potential interactions between changing levels of risk and the implementation of adaptation actions, and to develop adaptation pathways in partnership with the Greater London Authority.

A wide range of approaches

Climate change adaptation planning is a relatively recent issue for cities to grapple with and to date, greater attention has been focussed on climate change mitigation. 'Risk management', 'vulnerability based', 'policy first', 'scenario based impact assessment', 'disaster management', 'adaptive planning' and 'adaptation pathways' approaches and various combinations of the above have all been utilised with varying degrees of success (Wilby & Dessai, 2010; Ranger et al., 2010; IPCC, 2012). In many cases, cities are cautiously experimenting with approaches that they feel are most appropriate and will deliver the best outcomes. When employed, these approaches utilise valuable tools and offer insights but in most cases fall short of connecting assessment with decision making and implementation.

There is a need for structured approaches to adaptation planning that are incorporated into broader planning and decision making processes. No single approach is appropriate in all circumstances. The appropriateness of each approach to adaptation planning depends on the adaptation issue being addressed, including the time and geographic scale involved, the number and type of actors, and economic and governance aspects (IPCC, 2012). Research from Ranger et al. (2010), Walker et al. (2013) and the Intergovernmental Panel on Climate Change (2012) provide an informative overview of a range of adaptation planning approaches.

Adaptation planning challenges

Many challenges remain in urban climate change adaptation planning. A significant disconnect often exists between climate change assessments and subsequent adaptation planning and implementation. There is, therefore, a need for climate change assessment to be more closely integrated with adaptation planning and decision making. Improved methods need to be developed and trialled to overcome this disconnect and improve adaptation planning outcomes.

Traditional decision making tools have not yet been developed to manage the high degrees of uncertainty associated with long-term climate projections for parameters such as precipitation and tropical storms (Hallegatte, 2009). As climate models cannot provide the necessary inputs for current decision making frameworks, it is necessary to amend existing frameworks to enable them to account for the increased levels of uncertainty (Hallegatte, 2009). Adaptation planning approaches that can effectively incorporate uncertainty into the decision making process, or reduce the number of uncertainties, will be the most effective in managing future risks.

Millenium Bridge, London, UK

1 The project aims to provide system-scale understanding of the inter-relationships between climate impacts, the urban economy, land use, transport and the built environment and to use this understanding to design cities that are more resilient and adaptable. See: http://www.arcc-cn.org.uk/project-summaries/arcadia/

> There is a need for structured approaches to adaptation planning that are incorporated into broader planning and decision making processes. No single approach is appropriate in all circumstances.

Adaptation 'tipping points', 'limits' or 'thresholds' are issues that have not been considered sufficiently within many adaptation plans (Birkmann et al., 2010). However, defining thresholds that are widely accepted and can be used effectively in public policy decision making remains a significant challenge (Hall et al., 2012).

Adaptation planning must take into account the complex nature of urban systems. Within urban systems, risk and vulnerability are dynamic; they fluctuate through time due to physical, social and economic drivers. The design and implementation of adaptation strategies and policies can reduce risk in the short term, but may increase vulnerability and exposure over longer timeframes. Where possible, it is important to consider the dynamic nature of changing risk and vulnerability to reduce the likelihood of maladaptation (IPCC, 2012).

As climate change adaptation policies are usually implemented alongside policies for greenhouse gas mitigation, economic growth and sustainable development, this policy interaction can effectuate compromises and implementation obstacles, but potentially also co-benefits. Little analysis investigating these interactions exists and the mismatches and potential conflicts between different measures deserves more attention (Birkmann et al., 2010).

A combined framework

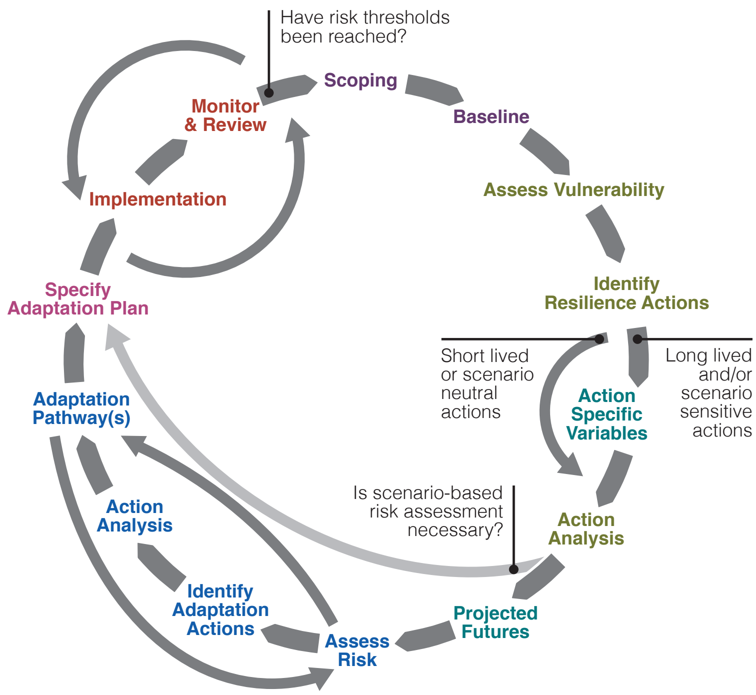
An initial finding from this research is that no single approach sufficiently encompasses the entire planning process from assessment through to planning, implementation, monitoring and review. Based on the key challenges and existing gaps identified as part of a review of adaptation planning literature, an original theoretical framework for risk assessment and adaptation planning has been developed (see Figure 1).

A number of principles for overcoming challenges in adaptation planning have been developed as part of this research. These have been derived from the adaptation planning literature and observed through participation in adaptation projects. Principles include:

- Articulating clear and achievable objectives is a critical component of the scoping phase, which will assist in communicating with stakeholders.
- Vulnerability to existing climate variability should be identified before considering future risks, which also provides the most effective foundation for understanding future adaptation thresholds (Wilby & Dessai, 2010).
- Priority adaptation actions identified in response to existing vulnerabilities should be flexible, short-term and robust. Where long-lived actions are identified, actions that are robust across a range of future scenarios should be prioritised (Hallegatte, 2009).
- Scenario based assessment is a powerful tool that allows for a dynamic consideration of risk, but it is not always required to inform adaptation planning, especially when there are limited financial resources for implementation (Wilby & Dessai, 2010).
- Adaptation pathways should seek to maximise flexibility within a system and minimise sensitivity to climate change scenarios by delaying decisions until critical thresholds are realised (Haasnoot et al., 2013).
- Monitoring and evaluation of critical variables is essential for understanding when thresholds are being approached and when additional adaptation actions need to be implemented to ensure an adaptation plan does not fail (Walker et al., 2013).

This framework for adaptation planning provides a structure for linking assessment and adaptation planning. This risk based approach combines critical elements from existing 'policy first', 'vulnerability', 'mainstreaming', 'adaptive planning' and 'pathways' approaches. The approach builds on frameworks proposed by Willows and Connell (2003), Ranger et al. (2010) Wilby and Dessai (2010) and Haasnoot et al. (2013). The framework provides a structure for each of the principles to be addressed during a specific adaptation planning phase. Critical

Figure 1 | Framework for climate change risk assessment and adaptation planning



components of adaptation planning can be conceptualised as one flexible and iterative process that links assessment, planning and implementation, however, the purpose of this article is not to provide a detailed description of each of the steps outlined in Figure 1.

Moving forward

Many cities already have experience in identifying social, economic, infrastructure and environmental vulnerabilities and then implementing appropriate programmes in response under the assumption of a stationary climate. Existing expertise needs to be utilised and further developed to design adaptation actions that increase resilience over the next decade, especially in developing countries. Where cities identify the need for long-lived assets or spatial planning interventions that respond to existing vulnerabilities, their design should account for future climate change (Hallegatte, 2009). This can be effectively achieved through a process of project level 'climate proofing' or the modification of design standards.

For adaptation planning in urban areas, developing the capacity for and undertaking 'vulnerability assessment' and 'climate proofing', monitoring and evaluation, and overcoming implementation challenges should be the immediate priority for urban authorities. However, there remains a need to make long-term strategic decisions under high degrees of climatic uncertainty and quantified risk assessment is an approach that has demonstrated significant potential to address this challenge (Hall et al., 2012).

The focus of the next phase of this research is to demonstrate how climate change adaptation pathways can be used as a tool to link area-wide scenario based risk assessment to the design of adaptation actions and implementation of action plans. This addresses a major policy challenge in an innovative manner. Internationally, relatively limited attention has been paid to characterising alternative pathways of future adaptation compared with the resources allocated to impact and vulnerability assessments, especially at the city scale. 'Adaptation pathways' have the potential to be utilised to support decision making in systems subject to environmental change. They are well suited to be combined with 'risk' and 'assumption based' approaches that consider adaptation planning over long timeframes in systems subject to high degrees of uncertainty (Haasnoot et al., 2012).

References

Birkmann, J., Garschagen, M., Krass, F., & Nguyen, Q. (2010). Adaptive urban governance: new challenges for the second generation of urban adaptation strategies to climate change. *Sustainability Science, 5*(2), 185-206.

GLA. (2011). *Managing risks and increasing resilience: The Mayor's climate change adaptation strategy.* London, UK: Greater London Authority.

Haasnoot, M., Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). Dynamic adaptive policy pathways: a method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change, 23,* 485-498.

Haasnoot, M., Middelkoop, H., Offermans, A., Beek, E., & Deursen, W. (2012). Exploring pathways for sustainable water management in river deltas in a changing environment. *Climatic Change, 115*(3-4), 795-819.

Hall, J. W., Brown, S., Nicholls, R. J., Pidgeon, N. F., & Watson, R. T. (2012). Proportionate adaptation. *Nature Climate Change, 2*(12), 833-834.

Hallegatte, S. (2009). Strategies to adapt to an uncertain climate change. *Global Environmental Change, 19*(2), 240-247.

Hewitt, C., Mason, S., & Walland, D. (2012). Commentary: the global framework for climate services. *Nature Climate Change, 2*(12), 831-832.

IPCC. (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation.* A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge, UK, and New York, NY, USA: Cambridge University Press.

Lemos, M. C., Kirchhoff, C. J., & Ramprasad, V. (2012). Narrowing the climate information usability gap. *Nature Climate Change, 2*(11), 789-794.

Ranger, N., Millner, A., Dietz, S., Fankhauser, S., Lopez, A., & Ruta, G. (2010). *Adaptation in the UK: A decision-making process* (Policy brief, September). London, UK: Grantham Research Institute on Climate Change and the Environment.

Walker, W. E., Haasnoot, M., & Kwakkel, J. H. (2013). Adapt or perish: a review of planning approaches for adaptation under deep uncertainty. *Sustainability, 5*(3), 955-979.

Wilby, R. L., & Dessai, S. (2010). Robust adaptation to climate change. *Weather, 65*(7), 180-185.

Willows, R. I., & Connell, R. K. (Eds.). (2003). *Climate adaptation: Risk, uncertainty and decision-making* (UKCIP technical report). Oxford, UK: UKCIP.

Fuzhou City, China

Urbanization and Its Impacts on an Estuarine Wetland Area in Fuzhou City, China

Yuanbin Cai and Xiangrong Wang

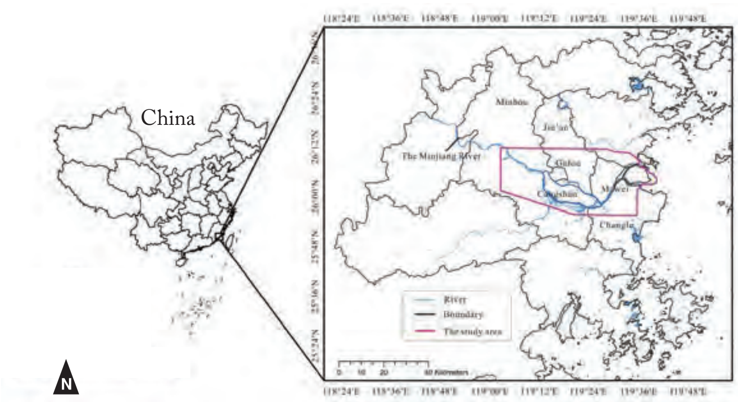
Globally, rapid urbanization and population growth have been common phenomena, especially in developing countries (Li et al., 2009). Given the fact that most major human settlements are located in low elevation coastal zones (McGranahan et al., 2007), land use/land cover (LULC) change induced by rapid urbanization has impaired the ecosystem functions of estuarine regions (Sato & Azuma, 2002). In these zones, urbanization is a major cause of natural wetlands loss, as it puts significant pressure on their structure and functioning. This is mainly through modification of the hydrological and sedimentation regimes, and the dynamics of nutrients and chemical pollutants, all of which results in natural wetlands degradation. In combination with wetlands loss due to sea level rise (albeit a smaller proportion), it is necessary to take urgent and practical countermeasures to prevent natural wetlands from the adverse effects of intensive human activities (Nicholls, 2004).

Urbanization research in China

China's reform policies have achieved greater prosperity and economic growth since 1978. To date, many large cities in the coastal economic zone[1], which is the preferred location for millions of internal migrants and overseas investors, have been the vehicles propelling China's economic growth (Chen et al., 2000). Ultimately, the country's total number of cities increased from 450 in 1989 to 660 in 2009, and its urban population rapidly increased from 312 million to 622 million (National Bureau of Statistics of China, 2010). However, with rapid development of the economy and urban expansion, the accompanied ecological deterioration and associated economic loss have been significant in these areas (Zhang et al., 2011). Given the importance of urban growth, land use/land cover (LULC) and the long-term adverse effects on ecological functioning, modeling LULC and urban growth has been the focus of many researches (Maktav & Erbek, 2005; Hardin et al., 2007; Geymen & Baz, 2008; Bhatta, 2009). However, less attention has been paid to the development of these models to understand the relationship between urban growth and related socio-economic processes that underlie land use

1 The coastal economic zone is a Special Economic Zone within an estuarine area for which the local government has targeted specific policies such as tax breaks, cheaper land and government support, in order to attract capital and foreign direct investment in China.

Figure 1 | Location of study area



change and urbanization (Irwin & Geoghegan, 2001). A multi-temporal approach using remote sensing (RS) and geographic information systems (GIS) will assist in determining whether these ecosystems have changed over time in terms of size, extent and quality. Additionally, as the government looks toward avenues for sustainable development through sound scientific decision-making, such an approach will aid in a more comprehensive understanding of the implications of urban planning and conservation of these natural wetlands.

This study principally focuses on the estuarine wetland area in Fuzhou City, southeastern China (see Figure 1). It is a key area for nature conservation within the domain of the west-side economic zone adjacent to the Taiwan Straits. This area provides a useful example due to its advantage of location, economic influence and prominence. Accordingly, our study attempts to examine the relationships among spatiotemporal patterns of built-up land, planning policies and socio-economic factors using time series information from remotely sensed data and statistical methods. It will lead to a better understanding of land use dynamics, driving forces for expansion patterns of built-up land, and thus provide useful references for planning researchers, urban planners and decision makers. We hope that this case study will offer practical implications for other international cities located in estuarine areas.

Urban expansion and driving forces analysis

Change statistics and the overall pattern of land use in the study area from 1989 to 2009 are shown in Table 1 and Figure 2. As shown in Table 1, for example, the number 113.11 (located in the first column and second row in the matrix) means there were 113.11km² of cropland converted to built-up land during 1989 to

Figure 2 | Land use maps of the study area

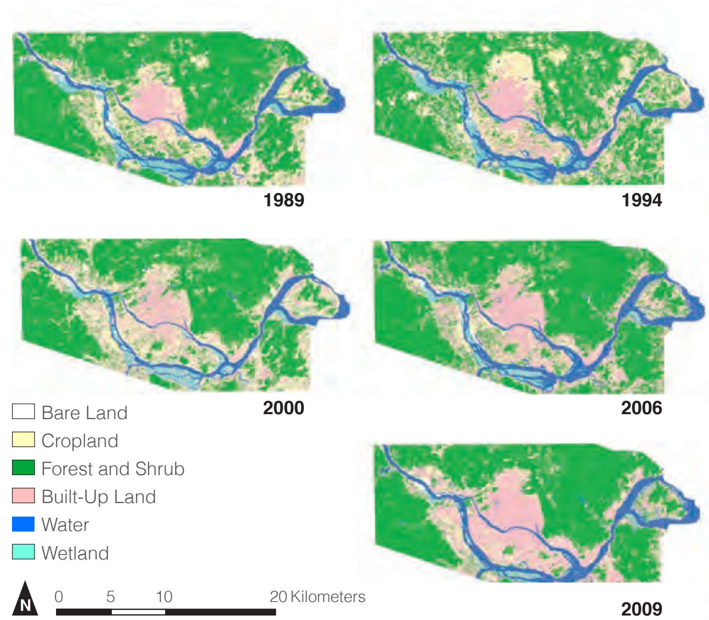


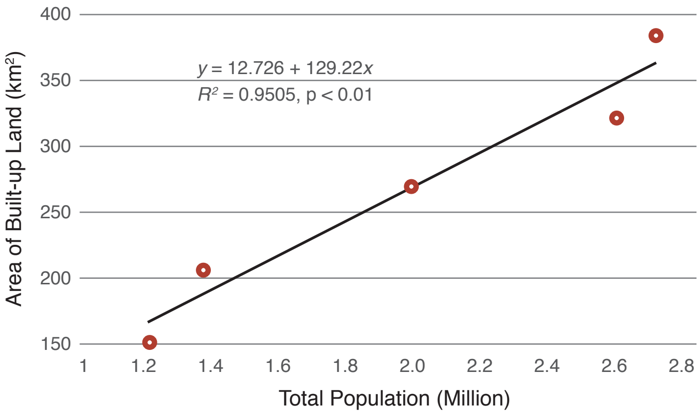
Table 1 | Land use transformation matrix in 1989–2009 (km²)

1989	2009						Sum
	Built-up Land	Cropland	Forest and Shrub	Water	Wetland	Bare Land	
Built-up Land	137.19	2.87	8.63	0.82	0.22	1.43	151.16
Cropland	113.11	30.80	180.70	8.47	0.03	2.33	335.43
Forest and Shrub	98.95	85.24	574.57	3.50	0.00	2.38	764.64
Water	14.31	5.33	1.66	130.15	2.97	1.34	155.77
Wetland	17.68	24.91	4.63	9.76	15.60	1.39	73.96
Bare Land	2.53	0.79	1.62	4.08	0.30	0.91	10.22
Sum	383.76	149.94	771.81	156.78	19.12	9.77	1491.18

2009, and the diagonal (i.e., 137.19, 30.8, 574.57, 130.15, 15.60, 0.91) were unchanged areas. Table 1 indicates that the LULC varied remarkably during the study period. That is, there were increasing trends for built-up land, forest and shrub, and water over these 20 years. The change in built-up land was most significant, as it increased by 232.60 km^2 (with an average changing rate of 11.63 km^2/yr), followed by forest and shrub, and water with an increasing rate of 0.358 km^2/yr and 0.05 km^2/yr, respectively. In contrast, cropland decreased by 185.49 km^2 during the study period, followed by wetland and bare land, which decreased on average by 2.74 km^2/yr and 0.022 km^2/yr, respectively. In general, forest and shrub, and water changed at a low speed, whereas built-up land, cropland, wetland and bare land changed at a relatively high speed. This is congruent with witnessed accounts of vast stretches of residences, economic development zones, and supporting infrastructure that were developed along the Minjiang River over these 20 years. It is noteworthy that the new development plan at Cangshan District, which aims at developing the new downtown of Fuzhou City and closely linking the city proper and surrounding counties, has been recently implemented and will further accelerate urban expansion. Our results show that approximately 64.25% of the newly increased built-up land area was converted from cropland, forest and shrub, water, wetland, and bare land, and as observed, has deteriorated natural and semi-natural ecosystems. Thus, recent urban expansion along the Minjiang River has placed a huge demand on land resources and resulted in massive land conversion from the other land types to urban built-up land.

During 1989 and 2009, the total population in the area grew by 173.11% from 1,190,000 to 3,250,000. However, it should be noted that rigid national policy for population mobility implemented between 1977 to 1984 prohibited the migration from ones birthplace, i.e., to seek employment, receive education, or settle in another city without special official certification. On the whole, this greatly depressed urban population growth and urban expansion during this period. Moreover, to accommodate a natural increasing population, additional settlements along the urban fringe were rapidly developed. This development is responsible for the increase in built-up land and encroachment on the natural wetlands. Figure 3 shows a significant linear regression relationship between the total population and built-up land in the study area, indicating the direct effect of population growth on urban land expansion. Figure 4A shows a significant positive correlation between total regional GDP and built-up area during the study period, indicating the direct

Figure 3 | Relationship between population growth and built-up land during 1989 – 2009



effect of GDP growth on urban land expansion. The same linear correlation exists between GDP per capita and built-up area (see Figure 4B). Figure 5 shows that the shares of primary industry (mainly farming, forestry, fishery, husbandry and ranching), secondary industry (mainly mining, refining, manufacturing, energy and water supply, and construction) and tertiary industry (mainly service and trade) of total GDP were 29.0%, 45.0%, and 26.0%, respectively in 1989; however, they were 9.6%, 47.4%, and 43.0%, respectively in 2009. Furthermore, Figure 6 shows a positive relationship between the proportion of non-agricultural population and built-up land area in the study area.

In the late 1990s, the State Council of China released a series of policies to support the development of the west-strait economic zones (mainly to promote the peaceful development of Cross-Strait relations) around the city proper and along the Minjiang River. This stimulated the establishment of intensive industrial parks, settlements, college parks, commercial facilities, and expressway systems along and across the Minjiang River, therefore, causing urban encroachment onto wetlands. Furthermore, natural occurring events such as typhoons and floods often cause significant environmental disasters and ecological loss in this area. The typical response to past flood damage prompted increasing construction of flood prevention infrastructure and required more investment in flood risk prevention. Over recent decades huge amounts of cropland, water bodies, and wetlands along the Minjiang River and its branches have been altered to meet the strong demand for typhoon and flood prevention. Unfortunately, in pursuit of short-term economic gains, local governments have failed to effectively manage land development in these flood-prone areas at the expense of considerable key wetlands.

Unfortunately, in pursuit of short-term economic gains, local governments have failed to effectively manage land development in these flood-prone areas at the expense of considerable key wetlands.

Quantifying and characterizing the impacts

This case study quantitatively characterizes the patterns of urban expansion and the relationship between built-up land and driving forces from 1989 to 2009 by using an integrated approach combining remote sensing and GIS techniques. It shows that built-up land increased from 151.16 km^2 in 1989 to 383.76 km^2 in 2009. Approximately 64.25% of the newly emerging built-up land was converted from cropland (29.47%), forest and shrub (25.78%), water (3.73%), and wetland (4.61%) during these two decades. Moreover, rapid development of infrastructure, facilities, industrial parks, and urban and rural settlements along the Minjiang River resulted in the eastward and southward expansion of built-up land. Additionally, the growth pattern of built-up land in the area is highly correlated with socio-economic factors, including GDP per capita and structure of industry. The observed environmental degradation including the loss of cropland and wetland as a result of the heavy pressure of rapid urbanization has greatly impaired the capacity of the city to meet the challenges of international competition and provide a sustainable environment. Fuzhou has a number of constraints that can be attributed

Figure 4A | Relationship between regional total GDP and built-up area during 1989 – 2009

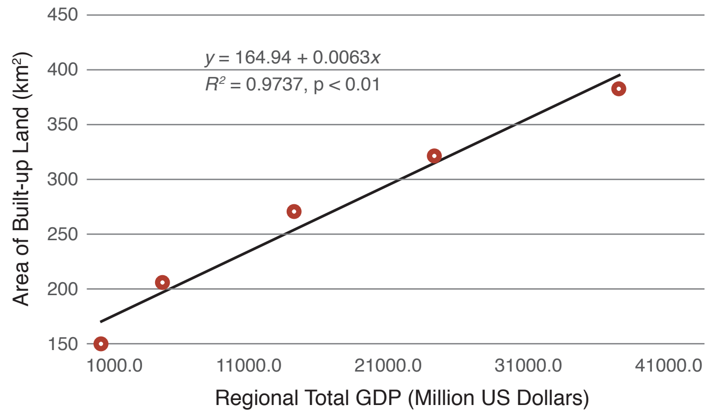


Figure 4B | Relationship between regional GDP per capita and built-up area during 1989 – 2009

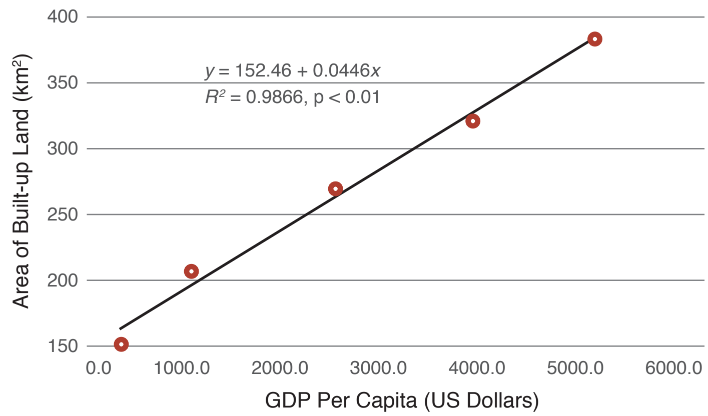


Figure 5 | Change in shares of industries in regional total GDP during 1989 – 2009

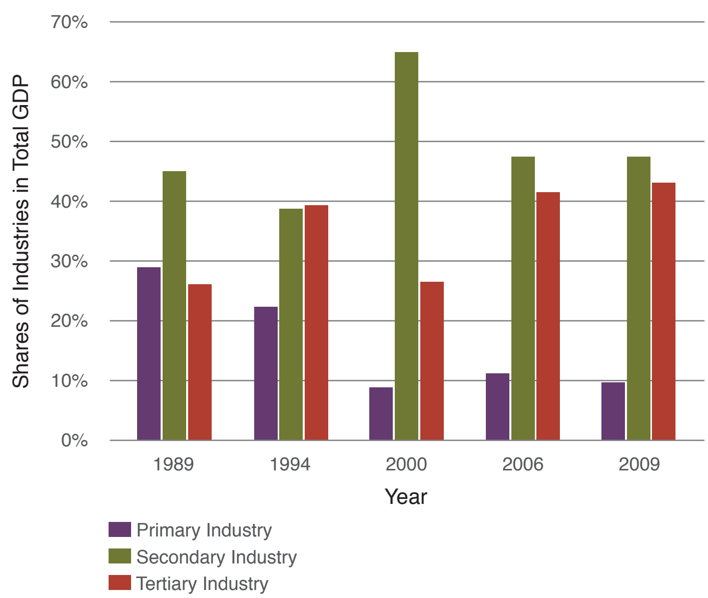
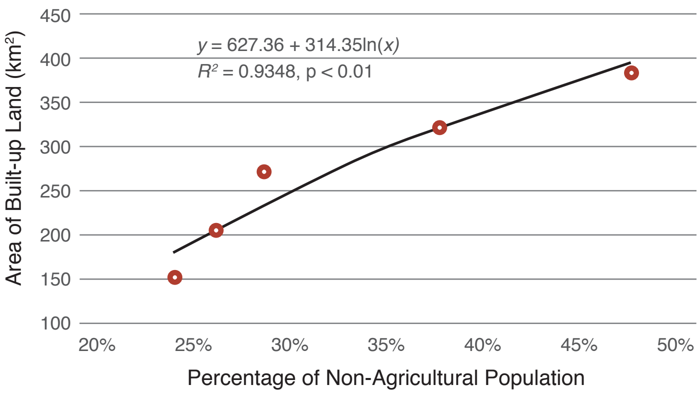


Figure 6 | Relationship between the proportion of non-agricultural population and area of built-up land in the study area during 1989 – 2009



to a large population with limited resources. Like estuarine metropolises worldwide, the trend toward ecological degradation from rapid urbanization brings huge ecological economic loss and it is not conducive to attracting investment and providing a suitable environment for development.

Overall, scientific and practical policies for land use and urban planning must be made to minimize the adverse effects of urbanization. That is to say, local government should continue its efforts for institutional innovation, rely on scientific and technological advances, strengthen the legal system of environmental protection, especially cropland and wetland preservation, and fully consider the diversity of those affected. Furthermore, coordination among administrative agencies needs to be strengthened to balance the conflicts between urban development and ecological conservation, ensuring sustainable land use. In the early part of city planning, the government should acknowledge possible ecological/environmental problems, such as wetland degradation, overpopulation, the lack of land resources, rapid urbanization and so on. However, in our study area this is far from being successful. Administrative agencies play the key role in preserving the natural resources, however, the role of public participation is just as, if not more, important. There are many ways currently in which the public can participate, for instance, through feedback consultation, an ecological hotline for reporting and information, and an environmental volunteer service, etc. These tools definitely play a key role in enhancing the public's awareness of the importance of environmental protection and we encourage the public to be actively involved in events throughout the important decision-making processes that influence the future of these ecologically sensitive areas.

References

Bhatta B. (2009). Analysis of urban growth pattern using remote sensing and GIS: a case study of Kolkata, India. *International Journal of Remote Sensing, 30*(18), 4733-4746.

Chen, M. R., Han, X. F., & Liu, S. Q. (2000). The effects of reclamation and sustainable development on coastal zone in Shanghai. *China Soft Science Magazine, 12*, 115-120.

Geymen, A., & Baz, I. (2008). Monitoring urban growth and detecting land-cover changes on the Istanbul metropolitan area. *Environmental Monitoring and Assessment, 136*(1-3), 449-459.

Hardin, P. J., Jackson, M. W., & Otterstrom, S M. (2007). Mapping, measuring, and modeling urban growth. In R. R. Jensen, J. D. Gatrell, & D. McLean (Eds.), *Geo-spatial technologies in urban environments: Policy, practice, and pixels* (pp. 141-176). Heidelberg, Germany: Springer.

Irwin, E. G., & Geoghegan, J. (2001). Theory, data, methods: developing spatially explicit economic models of land use change. *Agriculture, Ecosystems & Environment, 85*(1-3), 7-24.

Li, J. J., Wang, X. R., Wang, X. J., Ma, W. C., & Zhang, H. (2009). Remote sensing evaluation of urban heat island and its spatial pattern of the Shanghai metropolitan area, China. *Ecological Complexity, 6*(2), 413-420.

Maktav, D., & Erbek, F. S. (2005). Analysis of urban growth using multi-temporal satellite data in Istanbul, Turkey. *International Journal of Remote Sensing, 26*(4), 797-810.

McGranahan, G., Balk, D., & Anderson, B. (2007). The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment & Urbanization, 19*(1), 17-37.

National Bureau of Statistics of China. (2010). *Series achievements of economic and social development during the "Eleventh Five-year Plan" in China* (Report 3) (In Chinese). Retrieved from: http://www.stats.gov.cn/tjfx/ztfx/sywcj/t20110302_402706838.htm

Nicholls, R. J. (2004). Coastal flooding and wetland loss in the 21st century: changes under the SRES climate and socio-economic scenarios. *Global Environmental Change, 14*(1), 69-86.

Sato, S., & Azuma, M. (2002). Ecological and paleoecological implications of the rapid increase and decrease of an introduced bivalve Potamocorbula sp. after the construction of a reclamation dike in Isahaya Bay, western Kyushu, Japan. *Palaeoecology, 185*(3), 369-378.

Zhang, H., Zhou, L. -G., Chen, M. -N., & Ma, W. -C. (2011). Land use dynamics of the fast-growing Shanghai Metropolis, China (1979-2008) and its implications for land use and urban planning policy. *Sensors, 11*(2), 1794-1809.

Human settlements in Nakivubo wetland, Kampala, Uganda

Integrating Wetland Ecosystem Services into the Planning of Urban Landscapes in Developing Cities of East Africa: Lessons From European Riverine Wetlands and Floodplains

Najib Lukooya Bateganya, Judith Tukahirwa, Henry Busulwa and Thomas Hein

Wetlands are recognized worldwide for offering ecosystem services essential for human livelihood. In urban landscapes, some of the key wetland ecosystem services include, but are not limited to, flood attenuation, control of surface and ground water pollution, tourism and recreation, carbon sequestration and water supply (MEA, 2005). However, over years of urban and industrial development, anthropogenic induced modifications on riverine systems and wetlands have changed their physical, chemical, and biological functioning (Hein et al., 2009; MEA, 2005; Weilhoefer et al., 2008). This has not only deteriorated the resilience of these fragile natural systems, but has also increased the vulnerability of communities that directly or indirectly depend on them for the ecosystem services they provide.

This article provides an overview of the interactions between urban areas and wetland ecosystems including a discussion of drivers of change, pressures, impacts and potential responses within developing cities using the example of Kampala in East Africa. Some lessons of restoration efforts from Europe, particularly along the Danube River are used to underpin the significance of sustainable urban planning approaches, which take into account optimization of riverine and wetland ecosystem services to enhance ecosystem balance and resilience in cities.

Wetland transformations in Europe

On a global scale, the major driver to ecosystem change including wetlands is human population growth (MEA, 2005) coupled with urbanization and human settlements development, expansion of agricultural land and industrialization. In many European cities where the population density is very high, wetland areas have been converted for agricultural production. Coastal areas and large river floodplains (e.g., Rhine and Danube) have been heavily modified to enhance flood protection, improve navigation, and have been transformed by the construction of other highly engineered structures such as dams. It is estimated that such developments have led to a loss of approximately 95% of natural riverine wetlands in Europe, and the natural hydrological and

Dilapidated waste water treatment plant, Masaka, Uganda

biogeochemical functioning of the remaining 5% have been heavily altered (Junk et al., 2013).

The massive degradation of riverine systems and wetland areas, coupled with associated ecological and socio-economic impacts, have over the years led to increased awareness about their values, functioning and services in Europe. This is reflected by intensive research, and wetland policies and investment in restoration projects at different scales. In contrast, although such ecosystems still exist in developing countries especially along the Nile River and at the fringes of Lake Victoria in East Africa, they are under intense pressure (Co´zar et al., 2007) from increasing population growth and competing incentives for land use conversion (Adger & Luttrell, 2000) such as urban infrastructure and industrial development, agriculture and informal settlements. Hence, the ecological integrity is compromised and additional pressure is placed on urban systems, increasing the vulnerability (e.g., due to greater variability in water quality and quantity) of riparian communities within them. This vulnerability may be further exacerbated by the impacts of climate change (MEA, 2005).

Wetland ecosystem services in urban systems of East Africa

In East Africa, diverse wetland ecosystems including lagoons, creeks, and intertidal mudflats with sea grass beds, estuaries, saltpans, mangrove forests, thickets and sand beaches are crucial for the livelihood of millions of riparian communities due to the integrated nature of their relationship and functioning (Silvius et al., 2000). Consequently, their degradation threatens the survival of human populations which are directly or indirectly dependent on a multitude of ecosystem services they provide (Rebelo et al., 2010; Silvius et al., 2000) including the provision of food and enhancement of food security. In this region, population pressure is a key driver linked to wetlands degradation due to unsustainable expansion of agricultural land for food production, urbanization, infrastructure development and the increase in pollution from emissions. Additionally, this situation may be complicated further in the near future by climate change through temperature and hydrological changes (Junk et al., 2013; MEA, 2005). Further, climate change impacts will not only affect the fragile wetland ecosystems, but also have significant impacts on the vulnerable urban poor communities and infrastructure due to inadequate adaptive capacity and robust mitigation response mechanisms.

Historically, wetland ecosystems have generally been perceived by policy makers as 'wastelands' with no value unless drained (Adger & Luttrell, 2000). As a result, this has led to the under-valuation of their potential, motivated by incentives for conversion due to other competing land use demands. This is especially the case with industrialization and urban infrastructure development, which are considered to have higher economic returns on a short time scale. Also, in East African cities, wetlands and floodplain areas are hot spots for industries, poor urban settlements and agriculture. Consequently, key wetland ecosystem services such as storm water control/flood attenuation and pollution control (through wastewater and storm water treatment) are grossly compromised, therefore, exposing urban populations to climate variability impacts (especially flooding) and public health risks due to poor water quality.

The role of wetland ecosystems in cleansing wastewater effluent from adjacent East African cities as well as surface-runoff and untreated sewage from widespread low-income communities with inadequate access to sanitation is well documented (Kansiime et al., 2007a; Kansiime et al., 2007b; Kivaisi, 2001). The benefit of these wetland ecosystems as natural filters for the remediation of point and diffuse pollution sources is considered a sustainable option to ameliorate surface water quality (Co'zar et al., 2007; Kansiime et al., 2007a). This is particularly significant in many cities where conventional engineered wastewater treatment systems are expensive in terms of investment, operation and maintenance (Kivaisi, 2001).

The case of Kampala, Uganda

Kampala lies at the periphery of Lake Victoria. The Nakivubo and Nsoba-Lubigi wetland systems are important for the city's hydrological system and for regulating water quality. Nakivubo Wetland, in particular, is critically important for providing a buffer against pollution into Lake Victoria (Co´zar et al., 2007; Kansiime et al., 2007a) from point and diffuse sources including wastewater treatment systems, industries, and informal settlements with inadequate sanitation facilities. Unfortunately, these natural wetland systems are under extreme pressure from human development in the form of human settlements, industries and other urban structures (see Figure 1).

One of the major consequences of such development is increased investment and operational costs for water treatment due to the continued deterioration of lake water quality. In response, the National Water and Sewerage Corporation (NWSC) is considering investing over 200 million USD in a new water treatment facility.

Flood control through storm water attenuation is another key ecosystem service provided by wetlands in Kampala, especially during rainy season. Given the fact that over 15% of the city is within wetland areas (either ephemeral or perennial) (IUCN, 2003), a significant proportion of riparian settlements and public infrastructure is vulnerable to flooding. This has been evident, especially over the last two decades, by the widespread flood impacts including disruption to road transport systems and infrastructure damage, destruction of human settlements (including loss of human lives) and water related disease epidemics (especially cholera) during the wet season. The city's hydrological functioning is therefore importantly linked to the impacts of rapid and haphazard developments within the city, which create changes in the landscape including the widespread degradation of wetland areas.

Enhancing urban ecosystem balance and resilience: some take-away lessons from Europe

To underpin the role of wetlands and riverine systems including floodplains in urban landscapes, restoration projects for degraded systems in Europe under the implementation of The European Union Water Framework Directive[1] have demonstrated key lessons for developing cities. Increasing spatial heterogeneity

Figure 1 | A narrow wetland buffer strip due to city expansion towards Murchison Bay-Lake Victoria

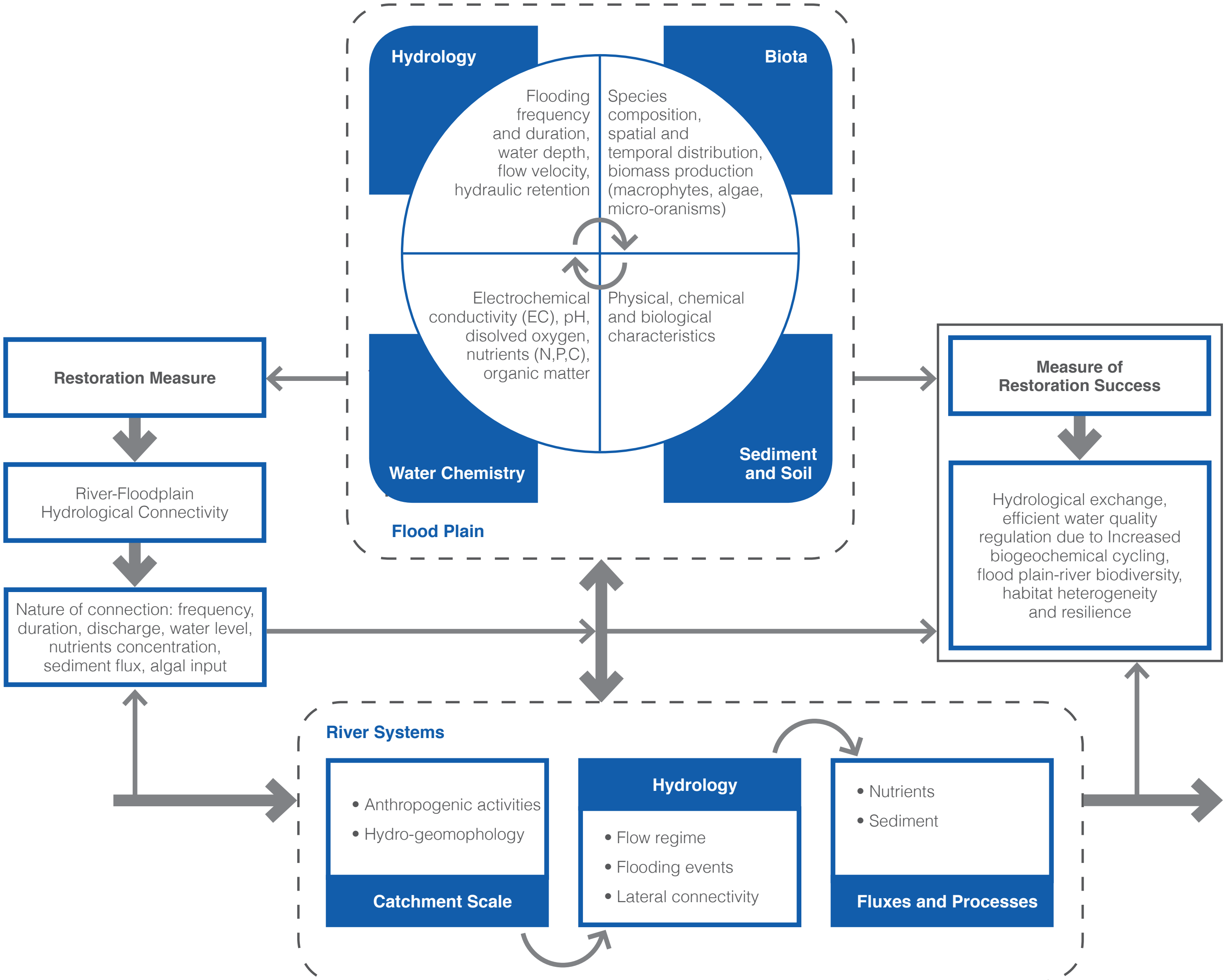
Source: Google Earth

and landscape dynamics of wetlands and riverine ecosystems are key goals of restoration efforts (Hein et al., 2009) in European systems. These two aspects enhance the efficiency of physical and biogeochemical processes, which regulate water quality and quantity on a temporal and spatial scale.

A conceptual model presented in Figure 2 illustrates the key components of restoration focusing on enhancing river-floodplain and wetlands interaction through hydrological connectivity along urban and agricultural landscapes of the Danube River. Restoration measures attempting to reconnect river-floodplain systems and wetlands in highly urbanized European landscapes are expensive but necessary, and provide critical lessons to developing cities in East Africa. First, restoring degraded riverine systems and wetland areas to promote their environmental benefits is complex and stochastic. Consequently, the extent and rate at which mitigation measures through restoration can replace the functions of natural systems remains uncertain (Gutrich & Hitzhusen, 2004). Also, research indicates that it takes more than just water to restore a wetland. Key aspects which influence wetland ecosystem functioning such as landscape setting, vegetation type and structure, hydrological regime, soil properties, topography, nutrient supplies, disturbance regimes, invasive species, and biodiversity must be integrated since they strongly influence the restoration process (Zedler, 2000). This therefore emphasizes the need for taking a precautionary approach and developing robust urban management plans to integrate the existing natural systems in urban landscapes of East African cities.

1 For further information see: http://ec.europa.eu/environment/water/water-framework/

Figure 2 | A conceptual model for a river-floodplain system. Restoration by hydrological connectivity enhances the interaction of a river system with floodplain biophysical (biota and soils/sediment) and chemical components which control the retention, transport and transformation of materials downstream; hence, regulation of water quality and hydrological balance.



Secondly, engineered systems developed in European systems leading to heavy modification of riverine landscapes have exhibited lower resilience to natural drivers of change, hence massive degradation of ecosystems especially in terms of biodiversity. This degradation has also been evident in Kampala as revealed by flooding and the deterioration of water quality in Lake Victoria. Therefore, to safeguard and possibly enhance the benefits of development for many communities who subsist on wetlands, and associated ecosystems, it's imperative that the benefits of natural ecosystems including their values for subsistence economies are recognized when planning and implementing development projects (Silvius et al., 2000) - such as urban public infrastructure and human settlements.

Lastly, the commitment shown by many countries in Europe to restore degraded riverine and wetland ecosystems to enhance their ecological integrity and promote the resilience of natural ecosystems underpins the importance of environmental sustainability for human prosperity. Therefore, following the conventional urban development path of degradation to restoration should not be adopted as the best template for planning in East African cities. The European Union Water Framework Directive in particular reemphasizes the fact that environmental issues do not respect physical boundaries, and political will and commitment to spearheading environmentally sustainable development is paramount.

Final thoughts

Urban development in East Africa has outpaced proper infrastructure planning. Landscape changes have compromised the integrity of wetlands by reducing and degrading the crucial ecosystem services they provide in space and time. Most importantly, the tradeoff for choosing infrastructure, settlements and industrial developments within wetland areas at the expense of enhancing their natural landscape functions has grossly compromised human prosperity and urban resilience to stochastic natural dynamics including climate change. Floods have destroyed urban infrastructure, human settlements and resulted in loss of human life; water quality in, for example, Lake Victoria has deteriorated, hence threatening the fundamental right of riparian populations to access a potable water supply; and livelihood strategies have been disrupted due to reduced supply of goods and services from the wetlands and lakes, etc.

The commitment shown by many countries in Europe to restore degraded riverine and wetland ecosystems to enhance their ecological integrity and promote the resilience of natural ecosystems underpins the importance of environmental sustainability for human prosperity.

Road construction and local wetland flooding, Kampala, Uganda

Water treatment plant near wetlands, Lake Victoria, Uganda

The restoration of degraded wetlands and riverine ecosystems in Europe has been a fundamental turning point for promoting human livelihood and environmental sustainability. It provides key lessons regarding the planning of urban landscapes and emphasizes the importance of promoting ecological balance and resilience of ecosystems within developing countries, especially East Africa. City drainage and flood management systems are not only critical in maintaining and stabilizing the urban hydrological cycle, but they are also critical in protecting human lives and property against climatic events, especially floods. In East African cities and towns where wetlands exist, landscape planning and development which integrates these ecosystems with infrastructure and human settlements development provides a robust option for resilience, protection, and prosperity. Integrating engineered drainage and wastewater treatment systems with natural wetland ecosystems is a more sustainable option for enhancing long term hydrological and ecological balance of urban systems.

References

Adger, W. N., & Luttrell, C. (2000). Property rights and the utilisation of wetlands. *Ecological Economics, 35*(1), 75-89.

Co´zar, A., Bergamino, N., Mazzuoli, S., Azza, N., Bracchini, L., Dattilo, A. M., & Loiselle, S. A. (2007). Relationships between wetland ecotones and inshore water quality in the Ugandan coast of Lake Victoria. *Wetlands, Ecology and Management, 15*(5), 499-507.

Gutrich, J. J., & Hitzhusen, F. J. (2004). Assessing the substitutability of mitigation wetlands for natural sites: estimating restoration lag costs of wetland mitigation. *Ecological Economics, 48*(4), 409-424.

Hein, T., Bondar-Kunze, E., Schiemer, F., Welti N., & Pinay, G. (2009). Effects of ecological restoration on biogeochemical processes in complex riverine landscapes. In H. G. Pardue, & K. T. Olvera (Eds.), *Ecological restoration.* New York: Nova Science Publishers.

IUCN. (2003). *Nakivubo Swamp, Uganda: Managing natural wetlands for their ecosystem services* (Case studies in wetland valuation, No. 7, May 2003). International Union for Conservation of Nature. Retrieved from: http://cmsdata.iucn.org/downloads/casestudy07nakivubo.pdf

Junk, W. J., An, S. Q., Finlayson, C. M., Gopal, B., Kvet, J., Mitchell, S. A., Mitsch, W. J., & Robarts, R. D. (2013). Current state of knowledge regarding the world's wetlands and their future under global climate change: a synthesis. *Aquatic Sciences, 75*(1), 151-167.

Kansiime, F., Kateyo, E., Oryem-Origa, H., & Mucunguzi, P. (2007a). Nutrient status and retention in pristine and disturbed wetlands in Uganda: management implications. *Wetlands Ecology and Management, 15*(1), 453-467.

Kansiime, F., Saunders, M. J., & Loiselle, A. (2007b). Functioning and dynamics of wetland vegetation of Lake Victoria: an overview. *Wetlands Ecology and Management, 15*(1), 443-451.

Kivaisi, A. K. (2001). The potential for constructed wetlands for wastewater treatment and reuse in developing countries: a review. *Ecological Engineering, 16*(4), 545-560.

Millenium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Wetlands and water synthesis.* Washington, DC: World Resources Institute.

Rebelo, L. -M., McCartney, M. P., & Finlayson, C. M. (2010). Wetlands of Sub-Saharan Africa: distribution and contribution of agriculture to livelihoods. *Wetlands Ecology and Management, 18*(5), 557-572.

Silvius, M. J., Oneka, M., & Verhagen, A. (2000). Wetlands: lifeline for people at the edge. *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere, 25*(7-8), 645-652.

Weilhoefer, C. L., Pan, Y., & Eppard, S. (2008). The effects of river floodwaters on floodplain wetland water quality and diatom assemblages. *Wetlands, 28*(2), 473-486.

Zedler, J. B. (2000). Progress in wetland restoration ecology. *Trends in Ecology & Evolution, 15*(10), 402-407.

Atlanta, Georgia, USA

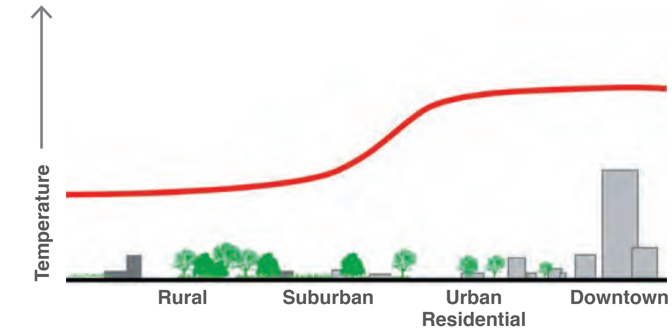
Getting off the Island: Understanding Urban Heat in a Changing World

Jason Vargo

Landscape influences temperature. You don't need a thermometer to understand it. If you want to relax on a summer day, you're better off spreading your blanket out under the shade tree at the park instead of on the black sea of asphalt where you parked your car. Such observations led to the (fairly well known) description of the *urban heat island effect*; the phenomenon of cities being warmer than neighboring rural areas (see Figure 1) (Oke, 1997). In some cases, the effect of urbanization on city temperatures has been shown to be comparable to warming from global climate change (Kalnay & Cai, 2003) and cities with more diffuse urbanization — sprawl — are experiencing more rapid increases in dangerous heat events than their compact counterparts (Stone et al., 2010). Such evidence directs attention to redesigning urban landscapes as a strategy for mitigating climate change (Stone Jr., 2009).

Warming in cities occurs through well-understood mechanisms, prominent among them the use of construction materials reducing surface reflectivity, the loss of vegetation creating a water deficit, and the production of waste heat from fuel consumption. Despite the experiential and scientific connections between urban landscapes and temperature, many municipal climate change action plans fail to address these drivers specifically (Stone et al., 2012). When cities look for guidance on mitigating urban heat, they likely find a number of resources for site-specific design recommendations, including vegetated roofs, tree planting, and reflective coatings for building and road surfaces. Policy recommendations for impacting regional change include stronger tree ordinances, fiscal support for conservation on private lands, design standards for streets and other public lands, and zoning and building codes (EPA, 2008). In addition to mitigation efforts, cities also pursue adaptation measures to reduce the impact of extreme heat on the health of their citizens. Strategies like extreme temperature warning systems, vulnerable population mapping with contact lists, and cooling center operations can prevent serious illness and death in heat wave conditions (Weisskopf et al., 2002). Taken

Figure 1 | Conceptual representation of urban warming profile



Surface and atmospheric temperatures vary over different land covers. The temperatures displayed above represent the concept of the heat island, not actual temperatures.

Source: J. Vargo, adapted from the US Environmental Protection Agency, http://www.epa.gov/hiri/about/index.htm

together, cities have a fair number of options to reduce urban heat and potential impacts.

Considering what we know within systems in flux

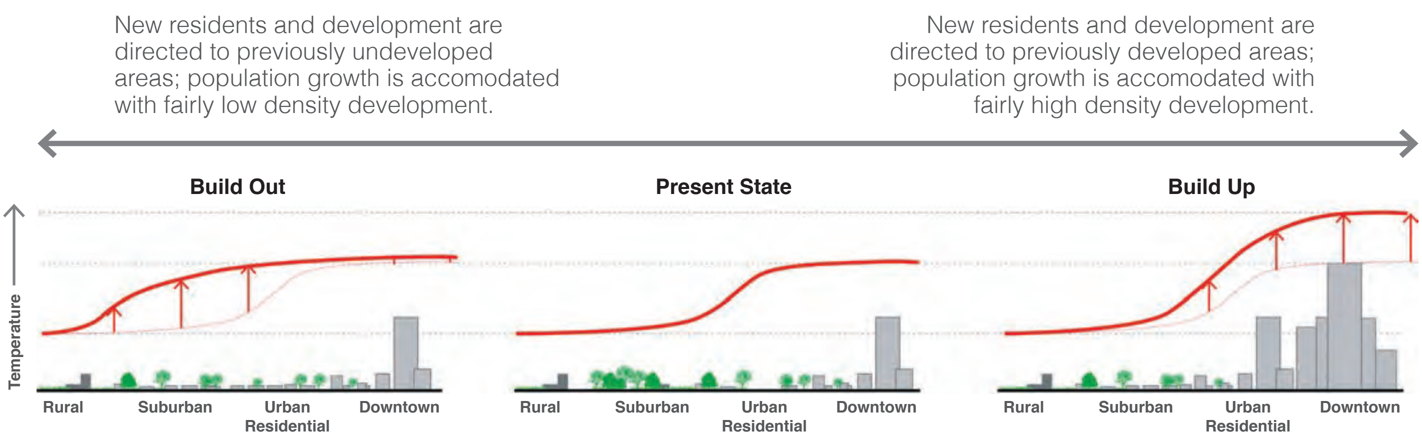
The understanding of how urban heat forms and the land cover strategies to deal with it is reasonably well described; however, the global climate system and the urban landscapes we inhabit are constantly in flux. With global climate change, the variability of regional climates has increased, creating more uncertainty for local governments and investors. At the same time, city and state budgets, particularly in the U.S., are becoming increasingly tight. Money spent on climate change preparation must be allocated towards solutions that have been tested within the context of growing urban populations and a changing global climate system in order to be both economically sensible and predictably beneficial.

Along a spectrum of metropolitan development

The quintessential graphical description of urban heat — the urban heat island transect (see Figure 1) — can help describe how our current understanding fits within dynamic systems. First consider the case of urban growth and impact on urban heat. Starting from a present day cityscape we can imagine two extremes for future urban form in a metro area: 1) a 'build out' model that adds most of its residents to previously undeveloped lands at low densities (i.e., more suburbs); or 2) a 'build up' model that directs residents and businesses toward existing infrastructures and economic centers (i.e., more dense urban developments) (see Figure 2).

Resulting temperatures along the transect might be expected to change as shown in Figure 2. 'Build up' is likely to concentrate urban materials and increase the magnitude of the urban heat island (difference between urban and rural temperatures). The logic presumes that if urbanization created urban heat, then new development should avoid dense urban landscapes; however, when a more diffuse pattern of development is adopted to accommodate new residents it is accompanied by larger heat-producing land cover conversions on a per capita basis (Vargo et al., 2013). This stretches the urban warming profile outward, without much change in the heat island magnitude[1]. Such a strategy could expose more people to higher temperatures and raise energy bills, as well as sacrifice large collections of natural landscapes, which provide valuable environmental services like cleaning water, facilitating recreation, and sustaining wildlife. Some of the most important and pressing questions for environmental planning relate to evaluating these tradeoffs under

Figure 2 | Conceptual model for heat island changes with urban growth models



Source: J. Vargo, adapted from the US Environmental Protection Agency, http://www.epa.gov/hiri/about/index.htm

1 Recent research shows that land cover changes occurring in suburban areas adjacent to static urban cores can affect temperatures within the urban cores themselves (Stone et al., In press).

alternative growth models. Other emerging research questions around the urban thermal environment relate to how, and if, the site-level strategies mentioned above - vegetated roofs, light colored building materials, etc. - can offset additional warming in the downtown that comes with build up, rather than out.

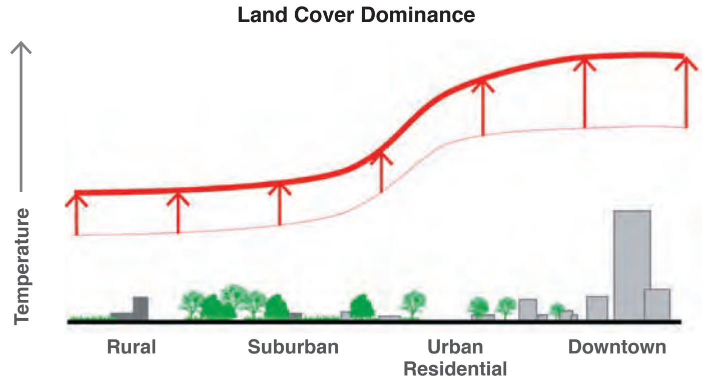
Rolling the future climate dice

Former NASA climatologist James Hansen and his colleagues liken the climate system to loaded dice, with global climate change increasing the chances of extremely hot weather in any given year (Hansen et al., 2012). Future temperatures in cities also depend on the global climate system. Increased variability in the system increases the probability of seeing extremely hot summers. Ensuring that the landscaping recommendations made today are effective under future conditions relies on understanding how the land cover influences on temperature interact with a warming climate. Hot weather, particularly long periods accompanied by drought, may reduce vegetation's ability to moderate local temperatures, decrease soil moisture and increase near surface temperatures, and/or create positive feedbacks with energy consumption and the production of waste heat. Two hypothesized scenarios of future thermal environments along the rural-urban transect are shown in Figure 3 that account for the combination of hot regional weather and local land cover effects on temperature.

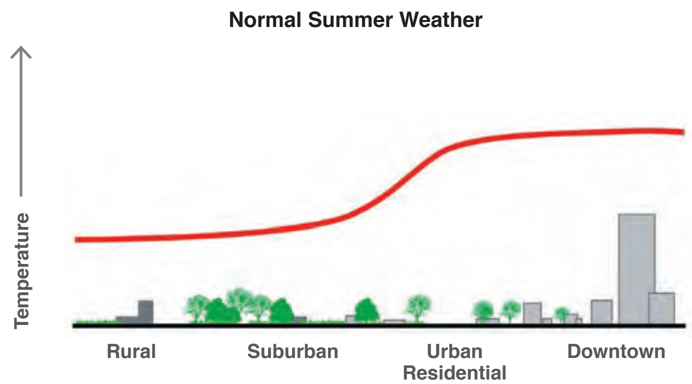
These scenarios raise questions about how risks for different populations change with more extreme weather, the effectiveness of present-day heat mitigation strategies, and whether more resources should be devoted to land cover mitigation or adaptation. If temperatures across a region are primarily influenced by weather, urban temperature moderation via landscape design may not be sufficient to merit investments in roof treatments and urban vegetation. If temperatures during extreme events are driven by land use, the same techniques may be the key to moderating the impact of extreme heat events. Faced with increased likelihood of such events, and limited resources to devote to urban mitigation and adaptation measures, cities need reliable information to guide actions.

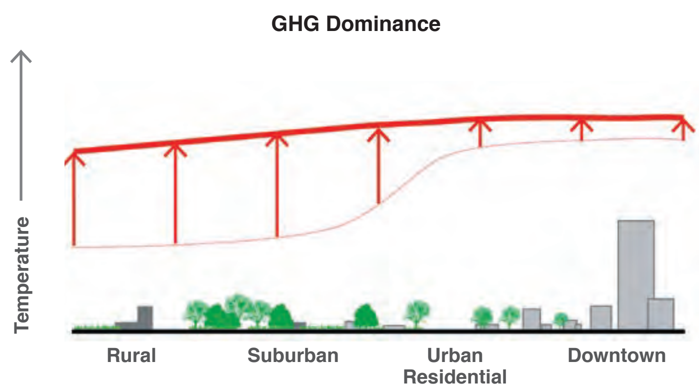
Depending on the direction urban growth proceeds and the influence global climate has on local land covers, the most appropriate set of mitigation and adaptation measures will differ from place to place (see Figure 4). Interdisciplinary efforts are required to inform cities of their current situations and the

Figure 3 | Conceptual model for heat island changes during a regional extreme heat event



Extreme hot weather raises rural temperatures but exacerbates the effect of urban land covers; the urban heat island grows.

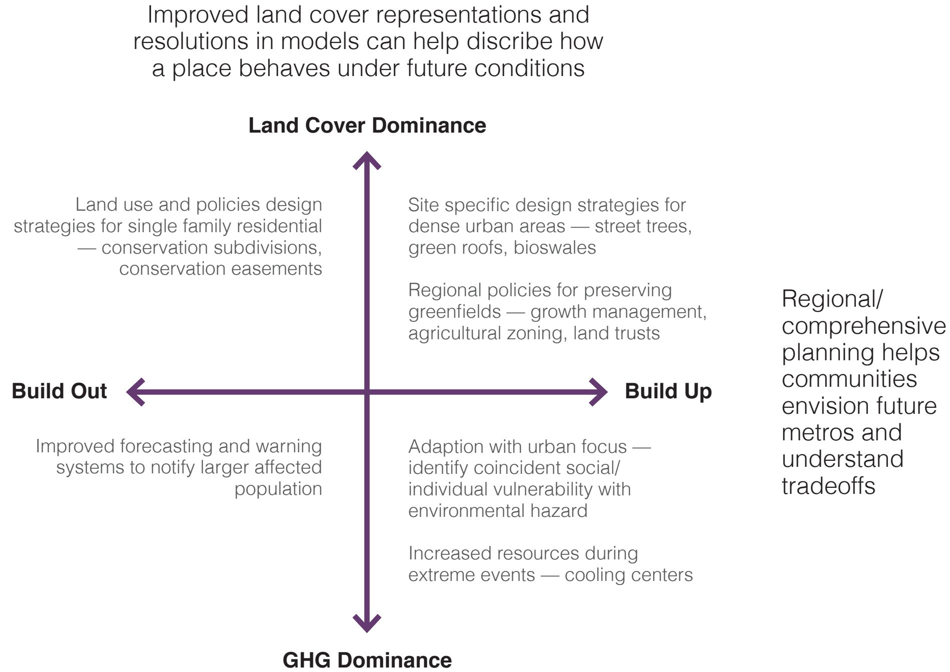




Extreme hot weather raises temperatures in rural areas more than in urban centers raising risks for all residents and virtually eliminating the urban heat island.

Source: J. Vargo, adapted from the US Environmental Protection Agency, http://www.epa.gov/hiri/about/index.htm

Figure 4 | Layout of most appropriate strategies and actions given various behavior of the urban thermal environment



> Uncertainty about urban patterns and thermal behavior of land covers under future extreme conditions raises questions about what should be done today. Fortunately, the increased use and sophistication of tools like thermal imagery, and meso-scale climate modeling can begin to consider land cover inside these dynamic systems.

potential impacts of decisions on future outcomes. Planning officials as well as political and community leaders play a role in moving along the horizontal axis by facilitating discussions among stakeholders from throughout the metro region. Climate and environmental scientists inform how local land covers respond along the vertical axis by detailing the interactions of land cover with natural systems and placing land use decisions within global contexts.

New tools to help understand the options

If we lived in a world without growing populations or global climate change, we currently have the tools necessary to deal with urban heat. However, for actual transitioning urban areas facing a changing climate, uncertainty about urban patterns and thermal behavior of land covers under future extreme conditions raises questions about what should be done today. Fortunately, the increased use and sophistication of tools like thermal imagery, and meso-scale climate modeling can begin to consider land cover inside these dynamic systems.

Satellite imagery is a tool that is increasingly utilized to describe the distribution of temperatures around urban areas.

Imagery products from satellites such as *Landsat* are available free of charge, offer coverage for nearly any location over multiple years, and include thermal data with reasonable spatial resolution. Some of my own work uses Landsat imagery to examine the land cover/temperature relationship in four US cities and under contemporary extreme conditions expected to become more common in future years. It finds stronger associations between the amount of surfaces like parking lots and buildings in a city and higher temperatures during extreme weather. These findings support the use of land cover-based strategies to moderate extreme heat in cities and also provide a map that can be used to prioritize siting of these investments. This is particularly true when temperature distribution is combined with maps of population-level vulnerability factors. In Chicago, concentrations of populations most susceptible to heat illness, such as low-income elderly people, are living in areas with sparse tree canopy that could potentially help mitigate the hot summer temperatures, and potentially related health effects. Such analyses can be used to prioritize urban vegetation efforts as well as emergency response planning. Empirical investigations of urban heat that are time and place-specific are possible using satellite imagery and other readily available census data in order to support public health and emergency response efforts.

Downscaled climate models are a second tool for understanding the interactions of climate and urban landscape modifications. Numerical climate modeling is increasingly being adapted to simulate smaller areas in greater detail. Improved land cover inputs for meso-scale models, like the Weather Research and Forecasting Model (WRF) can describe the climatic effects of land cover modification. They can evaluate the impacts of land cover policies, rather than single site interventions on a roof or in a park, in future climates. Examples of such work include the Climate Urban Land Use and Excess Mortality (CULE) study by Georgia Tech's Urban Climate Lab or the New York Climate and Health Project. These studies help demonstrate how and if vegetation and albedo strategies in dense urban areas can mitigate the temperature increases of concentrated built environments.

The most beneficial guidance for future urban development more carefully considers multiple urbanization options within changing global systems. Thermal imagery and improved climate models can inform cities of the best actions they can take to lower urban temperatures, but temperature is only one facet of our urban environment. The effects of preserving natural lands around cities and adding vegetation to existing dense urban landscapes go beyond simply lowering temperatures. New interactions between human and natural systems involve synergistic benefits and costs related to storm water management, changes in building energy demand, potential compounding of urban ozone, increased aeroallergen production, and regional wildlife habitat. More comprehensive evaluations of urbanization's impacts on other components of the natural environment should be modeled, as discussed by Viguié and Hallegatte (2012) to produce truly beneficial climate planning for cities.

References

Environmental Protection Agency (EPA). (2008). *Reducing urban heat islands: Compendium of strategies.* Climate Protection Partnership Division, U.S. Environmental Protection Agency. Retrieved from: http://www.epa.gov/heatisland/resources/compendium.htm

Hansen, J., Sato, M., & Ruedy, R. (2012). Perception of climate change. *Proceedings of the National Academy of Sciences, 109*(37), E2415-E2423.

Kalnay, E., & Cai, M. (2003). Impact of urbanization and land-use change on climate. *Nature, 423*(6939), 528-531.

Oke, T. R. (1997). Urban climates and global environmental change. In, R. D. Thompson, & A. Perry (Eds.), *Applied climatology: Principles & practices* (pp. 273-287). New York, NY: Routledge.

Stone Jr., B. (2009). Land use as climate change mitigation. *Environmental Science & Technology, 43*(24), 9052-9056.

Stone, B., Hess, J. J., & Frumkin, H. (2010). Urban form and extreme heat events: are sprawling cities more vulnerable to climate change than compact cities? *Environmental Health Perspectives, 118*(10), 1425-1428.

Stone, B., Vargo, J., & Habeeb, D. (2012). Managing climate change in cities: will climate action plans work? *Landscape and Urban Planning, 107*(3), 263-271.

Stone, B., Vargo, J., Liu, P., Hu, Y., & Russell, A. (In press). Climate change adaptation through urban heat management in Atlanta, Georgia. *Environmental Science & Technology.*

Vargo, J., Habeeb, D., & Stone Jr., B. (2013). The importance of land cover change across urban-rural typologies for climate modeling. *Journal of Environmental Management, 114,* 243-252.

Viguié, V., & Hallegatte, S. (2012). Trade-offs and synergies in urban climate policies: a case study in the Paris urban area. In C. Griffith (Ed.), *UGEC Viewpoints* (No. 8, November). Connecting Past and Present Lessons in Urbanization and the Environment (pp. 12-14).

Weisskopf, M. G., Anderson, H. A., Foldy, S., Hanrahan, L. P., Blair, K., Török, T. J., & Rumm, P. D. (2002). Heat wave morbidity and mortality, Milwaukee, Wis, 1999 vs 1995: an improved response? *American Journal of Public Health, 92*(5), 830-833.

Kolkata, India

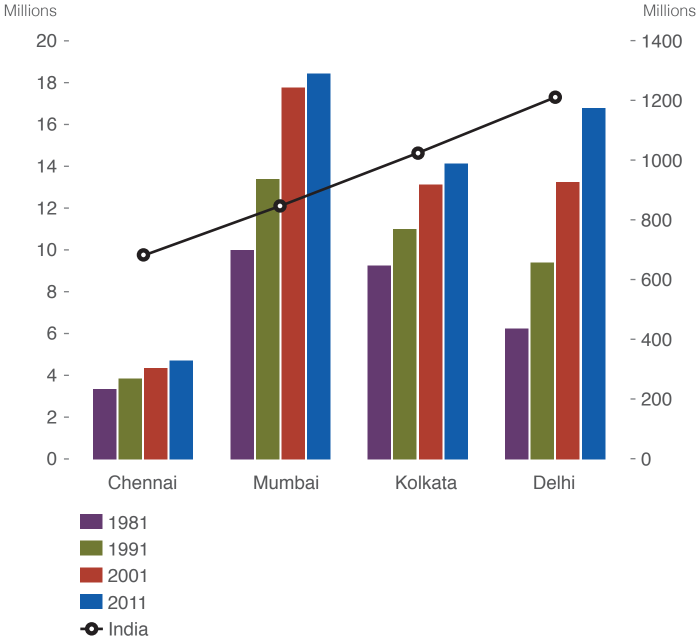
Rapidly Urbanizing Indian Cities: The Problem of Local Heat but a Global Challenge

Richa Sharma and P. K. Joshi

Urbanisation is increasingly modifying the micro-climate of cities across the globe. The most illustrious manifestation of such an altered urban climate is the Urban Heat Island (UHI) effect, which is currently experienced in almost all global megacities. However, in a developing nation like India, which falls second to China in terms of pace and scale of urbanisation, this phenomenon and its associated socio-environmental impacts are in need of further study (e.g., impacts on human health and liveability, biodiversity and the water cycle) (Pauchard et al., 2006). UHI monitoring thus becomes imperative, if not only from a human health perspective, since typical Indian cities are often very dense with large concentrations of the population inhabiting relatively small areas of land. In fact, India currently holds three of the world's megacities (Delhi, Mumbai and Kolkata), and Chennai, Hyderabad and Bangalore are expected to become megacities by year 2021 (UN, 2012) (See Figure 1). Given current pace and trends of urbanisation, India is often referred to as a *pseudo urbanised nation*, wherein the number of urban centres are increasing and expanding, but the basic infrastructure to support such vast systems is insufficient.

This work investigates the decadal changes in land use/land cover patterns in the four cities of Delhi, Mumbai, Kolkata and Chennai (see Figure 2), which are the loci of economic and political activities attracting in-migration in vast numbers. The research also focuses on the simultaneously implicated alterations in land surface temperature (LST) distribution across these cities and the concurrent shift in patterns of UHI and its intensities (Voogt & Oke, 2003). In urban areas, the conversion of vegetated land to non-vegetated built-up area results in a 'heating-up' of the land, which can be attributed to a number of factors. For example, the loss of vegetation cover results in decreased cooling due to the lack of evapo-transpiration and loss of moisture content (Grimmond, 2007). Moreover, the thermal properties of concrete structures are such that they absorb more heat and tend to remain hotter for

Figure 1 | Increasing population in the four metropolitan cities compared against national scale



Source: 2011 Census of India

Figure 2 | India and the four metropolitan cities - Delhi, Mumbai, and Kolkata are megacities (total population > 10 million)

longer time periods, and given their impervious nature, the lack of moisture inhibits their capability to cool down easily. Increasing urbanisation thus heats up cities, creating UHIs at local scales.

Remains of the fifth city (Tughlaqabad) in the Badarpur area of modern Delhi

The capital city — Delhi

Delhi is the capital city of India and has an ever-expanding history from ancient Mauryan times to the present era. The city has undergone phases of severe sprawl, particularly during medieval times and as such, is considered the 'Seven Cities'. Nowadays, urban sprawl is still occurring, but at a much faster pace.

Landsat TM satellite data was used to study the land use changes in the city from 1998 to 2011. In Delhi, the area of urban land use more than doubled from year 1998 (67.71 km^2) to 2011 (181.97 km^2). The urban land transformations in Delhi indicate a complex chain rather than simple from-to conversions. Overall statistics might indicate a slight increase in agriculture, but a more detailed analysis reveals environmentally degrading trends with infringement on neighbouring forest and riverbeds. Analysis reveals that agricultural land has been lost to built-up area, but in turn, there have been encroachments onto the Asola Bhati Sanctuary and Yamuna riverbeds for agricultural purposes. Sparse built-up area was also found to have decreased over the time period, which could be attributed to the transformation of sparse to dense built-up area. Another disturbing trend is the increase in open area, as open areas in the city are mostly lands that have been cleared for construction activities.

Simultaneously, Land Surface Temperature (LST) trends were analysed for the city with respect to land use patterns. The city experienced new hotter patches of LST in the north, which correspond to development of the Narela and Bawana industrial

> Cities like these can serve as role models for other urban agglomerations that are quickly evolving into megacities. Better planning, such as prudent green cover, creation of green roofs and walls, use of more appropriate materials and colors in urban constructions may aid in mitigating such impacts.

sites. The mean LST for land parcels that experienced urban transformation increased from 31.2˚C in 1998 to 32.5˚C in 2011. Analysis of UHI intensity for the years 1998 and 2011 reveals that parts of central Delhi (Old Delhi), including the industrial areas of Mayapuri, Azadpur and Narayana exhibit high UHI intensities across this time period. The Indira Gandhi Airport and Narela-Bawana industrial areas have emerged as new UHI peak zones in 2011 corresponding to drastic changes in land use in these areas. The LST of agriculturally dominated areas in the northern parts of the city was in range of 20-30˚C for year 1998, but has increased dramatically to 30-35˚C in 2011 after conversion to built-up land.

The entertainment capital — Mumbai

Mumbai is the capital city of the state of Maharashtra. The city is one of the most populous cities of the world, around 21 million, with the metropolitan area including neighbouring urban areas of Navi Mumbai and Thane. The city is often considered to be the financial capital of the country, as it is the wealthiest city with highest GDP, and has experienced soaring rates of in-migration especially during the 1990s. 1992 and 2009 Landsat images of Mumbai were produced and studied to analyse the urbanisation pattern and its impact on surface temperatures. Mumbai is shown to have expanded its built-up area from 183.15 km^2 in 1992 to 218.35 km^2 in 2009. Built-up area increased mainly at the expense of vegetation and inland water bodies such as lakes or ponds. Since the city is bound by ocean in the south and by Sanjay Gandhi National Park in the north, the city does not have much space for expansion. Consequently, intense pressure from competing land uses has caused a decline in the city's vegetation, water bodies and mangroves - 30% (52 km^2), 25% (10 km^2) and 26% (21 km^2) respectively. The only positive trend observed for Mumbai is the gain in forest cover by 15%. A more detailed analysis highlights that this gain has come from mangrove area in south-eastern parts of the city.

The LST distribution of the city for 1998 and 2009 illustrates elevated temperatures mainly in the city centre and in parts of the south. Areas of non-urban land that were converted to built-up area during this period got warmer by an average increase of 4.45˚C. The area in central Mumbai has shown a tremendous increase in temperature (15-20˚C), which corresponds with the construction of the new airport. The construction activities along the eastern coastal areas did not increase much beyond 4-5˚C, which could be attributed to their ocean proximity. Shivaji Nagar, Nirankar Nagar, New Gautam Nagar, Vaibhav Nagar and Ramabai Ambedkar Nagar in the south-east; Jogeshwari East near Sanjay Gandhi National Park; and Asalfa, Mairwadi, Mohili, Lokmanya Tilak Nagar and Dharavi in the central parts of the city have all advanced towards becoming potential locations for UHIs.

City of joy — Kolkata

Kolkata has been a city of importance ever since the colonial period when it served as the capital of the British Indian Empire and has been for many years the major port supporting the economy of the eastern states. Kolkata is now the capital of the state of West Bengal and is considered the financial and cultural centre of East India. The city is densely populated with a population of 14.1 million living within an area of 1886 km^2.

Kolkata has witnessed an increase in urban built-up land (76.81 km^2) between 1989 and 2010; and it has expanded in all directions, but more so on the eastern side of the river. Major contributors to the built-up category are plantations, agriculture (the largest contributor at 37.3 km^2) and agricultural fallow. Moreover, wetland vegetation, commercial plantation and open area also lost 8.2 km^2, 21.2 km^2 and 10.7 km^2 to built-up area, respectively. Land use dynamics show that plantation, agriculture and commercial plantation first became converted to sparse built-up land, which has subsequently transformed into dense built-up area.

The increase has been simultaneously marked by an elevation of 6.14°C in mean LST of the land that has undergone non-urban (1989) to urban (2010) transformation. In the north, areas that have emerged as heat island locations are located near the areas of Chitpur, Ghosh Bagan, Kadapara, Kashipur, Sawadagarh Pally and Ultadanga. On the western banks of the river, Hughly, Liluah, and North-east Ghusuri exhibited very high temperatures (> 35°C). On the eastern side of the river in the south, mainly the industrial regions of Taratala, Garden and other industrial sites along the riverbanks appear to be hotspots for heat island formation.

Newly constructed buildings on the wetlands of the Salt Lake area in Kolkata (above); the older, densely populated parts of Kolkata (below)

Typical congested area of Chennai

Most liveable city in India — Chennai

Chennai or Madras became a major industrial hub in the post-independence era and has been developing further as such. The city is rapidly progressing on the path of becoming a megacity following the footsteps of Delhi, Mumbai and Kolkata. Urban cover for Chennai has increased from 44 km^2 in 1991 to 70 km^2 in 2006. Lands for agriculture have experienced the largest major urban land transformation (22 km^2) and sparse built-up lands have been gradually converted to dense built-up area over this time. The city is majorly expanding in the southern parts including a mushrooming of industries.

The LST analysis for the city indicates that mean LST for non-urban to urban land cover increased by 8.3°C from 32.28°C in 1991 to 40.59°C in 2006. The areas of southern Chennai, including CIT Nagar, Moovender, Appavu Nagar, and industrial sites of Sarathi Nagar, Suriyammapet exhibited elevated temperatures in 2006 making these the potential sites for UHI development. In northern parts of Chennai, specifically near the main city area, Kasimedu, Grace Garden, Bhogipalayam, Wadia Nagar, Chintadripet and Seethakadi Nagar experienced an increase in LST from 1991 to 2006. This increase is evident in minimum, maximum and mean LST for urban areas from 1998 to 2009. The increase has been in the range of 6-7°C.

Moving forward

Cities across the globe are experiencing altered micro-climatic conditions with green (agriculture, plantation, etc.) to grey (built-up) land conversions resulting in the elevation of land surface temperatures. In response, a number of researchers are specifically focussing on UHI impacts on human health and heat waves (Tan et al., 2010), results of which are important for urban planners and policymakers. The present research highlights urban land transformations in India and their impact on urban surface temperatures which is imperative for managing and mitigating the phenomenon of UHI in cities. Such an assessment accentuates the need and scope for policy interventions to curb the rising temperatures in urban areas. Though rapidly urbanising, the nation is still largely rural and is undergoing what is known as pseudo-urbanisation. The work emphasises the plight of the four metro cities of India, and how these swiftly urbanising landscapes are consequently experiencing elevated temperatures. These results can serve as a source of learning for other Indian cities such as Ahmedabad, Jaipur, Kanpur, Surat, Poona and Lucknow, all of which are following the development footprints of the four metropolitan cities (Joshi et al., 2011). Currently, these cities are urbanising rampantly without consideration of the potential indirect impacts associated with such drastic land use/cover changes.

The good news is that the national government of India is taking steps towards better planning and coordination of urban development and renewal. One such urban renaissance project in India is the Jawaharlal Nehru National Urban Renewal Mission (JNNURM). The UHI effect is treated as a major environmental issue under the project's module, Environmental and Social Safeguards. Policy related to land acquisition (Land Acquisition Act, 1984) and provisions of the Environmental Impact Assessment (EIA) or Environment Protection Act (1986) function as umbrella legislation and tend to address this issue, but in a very diluted and indirect manner. Other commendable initiatives by government include programmes such as the Green Rating for Integrated Habitat Assessment (GRIHA) and Association for Development and Research of Sustainable Habitats (ADaRSH) for promoting green buildings and help to find solutions for a number of environmental issues.

However, no policy framework has been dedicated solely towards combating this issue. One city showing progress in this regard is Surat in Gujarat. The city has often been lauded as exemplifying smart urbanisation in the overburdened country of India. It has made improvements in existing infrastructure, health and waste disposal sectors while developing on economic fronts. Another good example is the city of Ahmedabad, which for instance has launched the 'Heat Action Plan' to combat the ill effects of UHI. Cities like these can serve as role models for other urban agglomerations that are quickly evolving into megacities. Better planning, such as prudent green cover, creation of green roofs and walls, use of more appropriate materials and colors in urban constructions may aid in mitigating such impacts. Governments across the globe, specifically in developing countries, must focus on efficient urban planning strategies that should be modified and adapted examples of best practices for sustainable development in the true sense. Our research is a first step towards assisting in this endeavour.

Acknowledgments

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References

Grimmond, S. (2007). Urbanization and global environmental change: local effects of urban warming. *Geographical Journal, 173,* 83-88.

Joshi, P. K., Bairwa, B. M., Sharma, R., & Sinha, V. S. P. (2011). Assessing urbanization patterns over India using temporal DMSP-OLS night-time satellite data. *Current Science, 100*(10), 1479-1482.

Pauchard, A., Aguayo, M., Pena, E., & Urrutia, R. (2006). Multiple effects of urbanization on the biodiversity of developing countries: the case of a fast-growing metropolitan area (Concepcion, Chile). *Biological Conservation, 127*(3), 272-281.

Tan, J., Zheng, Y., Tang, X., Guo, C., Li, L., Song, G., Zhen, X., Yuan, D., Kalkstein, A. J., & Li, F. (2010). The urban heat island and its impact on heat waves and human health in Shanghai. *International Journal of Biometeorology, 54,* 75-84.

UN. (2012). *World urbanization prospects: The 2011 revision highlights.* New York: United Nations.

Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. *Remote Sensing of Environment, 86*(3), 370-384.

Melbourne, Australia

Combating the Urban Heat Island Effect: Strategies for Enhancing the Cooling Capacity of Green Infrastructure In Melbourne, Australia

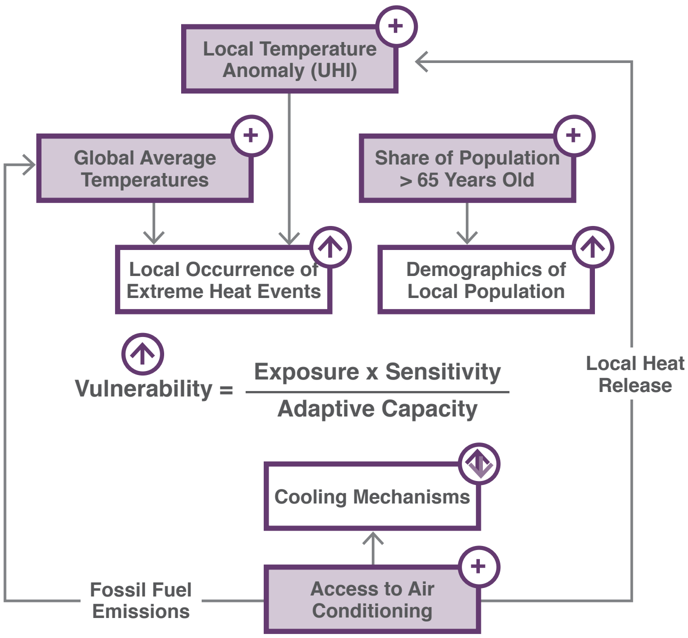
Alexei Trundle, Karyn Bosomworth and Darryn McEvoy

Australia is popularly portrayed as a land of drought and flooding rains, beset by numerous and varied natural disasters; from devastating wildfires through to tropical cyclones. However with one of the world's most heavily urbanised populations (some 89% of the country's 22 million inhabitants), the most deadly impact of the nation's characteristic climatic variability over the past three decades has been that of extreme heat events. As the climate changes, the frequency of these events is likely to increase: if emissions continue to rise at current rates, the annual number of consecutive three day periods with maximum temperatures above 37°C/98.6°F in Australia's second largest city, Melbourne, is likely to increase from an historic average of one to eight by 2100, while the annual number of days over 40°C/104°F is projected to increase fivefold over the same period (AECOM, 2011).

The Urban Heat Island (UHI) effect is a complex phenomenon created by built infrastructure absorbing, trapping and in some cases directly emitting heat. In the Melbourne Central Business District, the UHI has been observed to result in night-time surface temperatures 4°C warmer than the city's rural surrounds (Coutts et al., 2008). With a predicted population increase from 4 million currently to 6-8 million by the middle of this century, the city's UHI is expected to intensify and spread as infill continues and the urban boundary expands. Accompanying this is a rapidly ageing population, with citizens aged 65 and over projected to increase from 14% currently to between 22-24% of the city's population by 2056 (ABS, 2008).

The combination of global warming, enhanced heat retention within the local micro-climate, and an ageing population will result in a steadily increasing level of vulnerability to what is already a serious climate-based risk for the city's inhabitants (see Figure 1). To date, autonomous approaches to the management of extreme heat have relied heavily upon the installation of air-conditioning in households and workplaces, resulting in a re-enforcing and arguably maladaptive feedback loop, increasing both the local UHI effect and fossil-fuel driven climate change. A more strategic, policy-driven approach for adapting to and managing urban heat is needed if vulnerability to extreme heat events is to be addressed.

Figure 1 | Representation of current and projected extreme heat vulnerability in Melbourne



The re-integration of Green Infrastructure (GI) — living plant matter such as street trees, green roofs and vertical gardens — into the urban form is increasingly being internationally recognised as an opportunity to provide multiple benefits to cities. However in Australia, the uptake of urban GI policies, programs and projects has lagged behind that of North America, the UK and Europe. As part of a wider, interdisciplinary study assessing GI-based urban heat reduction, this research sought to develop an understanding of actor-based attitudes to both GI and the UHI from a broad spectrum of stakeholders (including State and Local government planners; landscape architects; engineers; GI suppliers; academics and standards development organisations). Analysis of these views — as well as the legislation and information that shaped them — enabled the research to identify the key barriers and opportunities for enhancing the implementation of GI across Melbourne.

Which Urban Heat Island? Addressing scale and spatial variation

As a preliminary component of the research, stakeholder understandings of the concepts of both UHI and GI were assessed through a semi-structured interview process. Analysis of these perceptions of Melbourne's UHI revealed that if GI implementation is to be targeted at urban hotspots — and its cooling benefits accounted for in planning processes — stakeholder literacy in both the nature and distribution of Melbourne's thermal footprint must first be significantly improved. A number of participants were unable to define the UHI effect, with the most developed explanations only referring to simplified depictions of UHI city-wide transects recalled from public policy documents, research publications and media articles. Such transect depictions related solely to nocturnal mesoscale surface temperatures (see, for example, City of Melbourne, 2012), often leading to misperceptions of the exposure of outer-western municipalities to localised extreme heat (areas characterised by day-time maximums in excess of those of the inner city). In the case of inner-city decision-makers, the significance of localised variations in urban heat was largely not understood, resulting in a perceived inability to address local 'hotspots'.

The potential for reduction of indoor and ambient temperatures through vertical GI was not referred to by any of the interviewees, possibly as a result of the prevalence of aerial thermal imagery, which implicitly directs planners to focus on the cooling of skyward-facing external surfaces such

Figure 2 | Scales of Melbourne's thermal footprint (adapted from Loughnan et al., 2013; City of Melbourne, 2012)

as rooftops and paved streetscapes. Figure 2, for example, shows three different depictions of Melbourne's night-time thermal footprint. However, the evident 'hotspots' differ significantly, potentially resulting in development of different heat reduction actions: the left-hand, city-wide image may lead to a planner targeting the inner city; the central image, GI implementation toward streetscapes; while the right-hand street-level image illustrates heat loss and retention in buildings, and even heat trapped beneath parked cars (which would otherwise appear to be 'cool' in an aerial image).

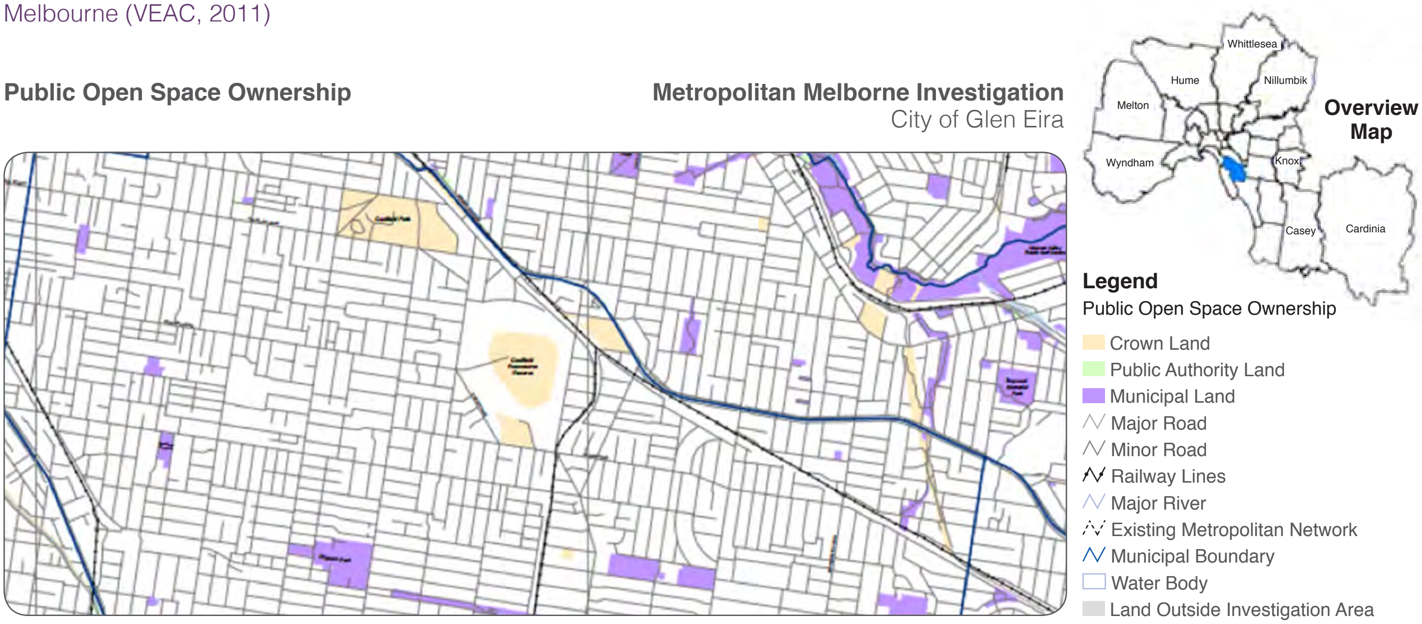
Spatial variations in other environmental, governance-based and socio-demographic factors were identified as being central to effective implementation of city-wide, GI-based urban heat reduction strategies. For example, areas of western Melbourne experience average annual rainfall of less than half of some of those in the eastern suburbs, a factor that a number of interviewees attributed to both the reduced presence of GI in the west as well as the region's predominantly higher average day-time temperatures. These considerations were compounded by the decade-long Millennium Drought (1997-2009), during which public campaigns for reduced potable water use resulted in a shift to drought-tolerant vegetation types as well as replacement of GI with hard surfaces, further reducing evapotranspirative cooling capacity. With urban run-off (453 Gigalitres per annum) currently exceeding levels of potable water consumption (412 Gigalitres), enhanced stormwater retention and use represents a key opportunity to simultaneously reduce urban heat, potable water consumption and stormwater infrastructure demand across the city (LVMAC, 2011).

Turning the tide: reducing urban heat in a growing city

Private land accounts for 84% of the metropolitan Melbourne area (VEAC, 2011). While direct, government-led GI implementation programs have clear public benefits, the capacity to reduce the city's thermal footprint — or, applying a different metric, achieve a net increase in urban GI coverage — without private-sector incentives and engagement was found to be limited. For example as shown in Figure 3, Glen Eira — an inner city municipality — has an existing open space network covering less than 6% of the township's total land area.

Although city-wide estimates of GI coverage are not available, analysis of suburb-level assessments suggested that increased street tree coverage over the last decade has been offset by a reduction in privately-owned green space. For example in the locality of Broadmeadows, a 38% increase in the suburb's street trees between 2000-2009 was almost entirely offset by a concurrent 4% decrease in the number of private trees, resulting in a net tree cover increase of only 2% across the suburb (VEAC, 2011). These local trends are consistent with both widespread urban consolidation in inner and middle suburbs as well as an increase in median lot coverage in new residential builds; factors that significantly reduce the space available for ground-level GI.

Figure 3 | Extract from a Victorian Environmental Assessment Council (VEAC) analysis of land ownership across Metropolitan Melbourne (VEAC, 2011)



Drivers for private implementation of GI were found to differ from and in some instances conflict with the public benefits derived from GI on state-owned land. One interviewee provided an example of an indoor vertical garden — installed by a company for marketing purposes — that required installation of an ultraviolet lighting system to survive, effectively negating potential cooling and energy efficiency benefits. Conversely the insulative benefits of green roofs and walls for indoor environments (a key factor identified in reducing individual vulnerability to extreme heat events), are not directly accounted for in aerial surface-temperature measurements of urban heat. As a result, the research proposed a dual-track approach to government strategies for enhancing GI coverage; on one hand communicating and incentivising private benefits to landholders, while on the other, optimising the public goods derived from a holistic increase in green cover through direct intervention in areas such as Crown road reserves (land adjacent to roads that is managed by the Victorian State Government), which make up 45% of Melbourne's total publicly-owned land (VEAC, 2011).

International studies suggest that a 10% increase in total urban GI coverage could result in UHI reduction of up to 2.5°C (Forest Research, 2010). Unlike many European and British cities however, Melbourne's urban footprint is continuing to spread rapidly, in tandem with consolidation of the city's characteristic low-density detached housing stock. Any attempts to emulate international strategies for GI-based cooling must therefore take into account existing planning processes, which are projected to increase UHI intensity by 2.6°C by 2030 (Coutts et al., 2008). As a consequence, the opportunities for enhancing GI-based cooling that were identified in this research were necessarily wide-reaching, crossing and integrating departmental responsibilities; national, state and municipal planning regimes; and areas of public and private tenure.

> Analysis of these perceptions of Melbourne's UHI revealed that if GI implementation is to be targeted at urban hotspots — and its cooling benefits accounted for in planning processes — stakeholder literacy in both the nature and distribution of Melbourne's thermal footprint must first be significantly improved.

Targeting benefits: scales, sectors and stakeholders

In the case of Melbourne, GI implementation requires consideration of Australia's three-tiered governance system, including 31 discrete municipal councils across the Melbourne metropolitan area. At a municipal level, the research team has developed a *Green Infrastructure Heat Reduction Guide* (Norton et al., 2013), with the goal of enabling council-level decision-makers to integrate urban cooling benefits into GI projects and programs.

Policy recommendations at a national scale focuses on site-level GI implementation, and includes proposals such as integration of GI into the *Building Code of Australia* (identified by developers and architects as the core enabling regulatory document for mainstreaming changes at private building sites) as well as advocacy for improved weighting and identification of GI benefits in voluntary accreditation systems, such as the *Infrastructure Sustainability Rating Tool* and the Australian *Green Star* scheme.

State Government recommendations are divided across three key departmental portfolios due to differing expertise, jurisdictional capacities and motivations for implementing GI-based UHI reduction initiatives. Guidance for Health identifies opportunities to educate children through integration with preventative health programs, resourcing for development of GI master plans for vulnerable urban 'hotspots' as well as consideration of related co-benefits (such as improved air quality and encouragement of active transport options). Transport portfolio recommendations focus on reducing regulatory barriers around street trees (the GI type identified by the study's thermal research team as having the greatest capacity to cool streetscapes), such as set-back regulations. Key messages for the Planning and Community Development portfolio focus on incentivising maintenance or installation of GI at a site level through the development application process.

Envisioning a resilient and liveable future Melbourne

As we adapt to changing climatic and social conditions, it is increasingly evident that static assumptions about the nature of our cities, their citizens and the environment that encompasses and surrounds their built form can no longer provide a sufficient basis for formulating effective and sustainable public policies and initiatives. Further, as shown in this Melbourne case study, both government-driven and autonomous responses to immediate impacts — climate and non-climate alike — can prove to be maladaptive either in the long-term, or when considered as part of a broader urban system. If our cities are to provide resilient, liveable environments for their citizens into the future a new, dynamic model is required, capable of integrating tiered political, actor-based and legislative regimes with local contexts and variability.

Acknowledgements

This paper builds upon the findings of the study, 'Responding to the urban heat island: optimising the implementation of green infrastructure', funded by the Victorian Centre for Climate Change Adaptation Research (VCCCAR). The input of VCCCAR as well as that of collaborative researchers from University of Melbourne and Monash University, is gratefully acknowledged.

References

AECOM (2011). *Adaptation of Melbourne's metropolitan rail network in response to climate change* (Report prepared for the Department of Climate Change and Energy Efficiency). Commonwealth Government of Australia.

Australian Bureau of Statistics (ABS). (2008). *3222.0 – Population projections, Australia, 2006 to 2101*. Commonwealth Government of Australia. Retrieved from: http://www.abs.gov.au/Ausstats/abs@.nsf/mf/3222.0

City of Melbourne (2012). *Urban forest strategy: Making a great city greener 2012-2032*. Retrieved from: http://www.melbourne.vic.gov.au/Sustainability/UrbanForest/Documents/Urban_Forest_Strategy.pdf

Coutts, A. M., Beringer, J., & Tapper, N. J. (2008). Investigating the climatic impact of urban planning strategies through the use of regional climate modelling: a case study for Melbourne, Australia. *International Journal of Climatology, 28*(4), 1943–1957.

Forest Research (2010). *Benefits of green infrastructure* (Report to the British Government Department for Environment, Food and Rural Affairs). Retrieved from: http://www.forestry.gov.uk/pdf/urgp_benefits_of_green_infrastructure.pdf/$file/urgp_benefits_of_green_infrastructure.pdf

Living Melbourne Ministerial Advisory Council (LVMAC). (2011). *Living Melbourne, living Victoria roadmap*. Victorian State Government Department of Sustainability and the Environment. Retrieved from: http://www.water.vic.gov.au/__data/assets/pdf_file/0005/135356/3770_DSE_Living_Victoria_Roadmap_1.3MG.pdf

Loughnan, M. E., Tapper, N. J., Phan, T., Lynch, K., & McInner, J. A. (2013). *A spatial vulnerability analysis of urban populations during extreme heat events in Australian capital cities* (Report for the National Climate Change Adaptation Research Facility). Retrieved from: http://www.nccarf.edu.au/publications/spatial-vulnerability-urban-extreme-heat-events

Norton, B., Williams, N., Coutts, A., Harris, R., Bosomworth, K., Trundle, A., Livesley, S., & McEvoy, D. (2013). *Planning for a cooler future: Green infrastructure to mitigate urban heat* (Report to the Victorian Centre for Climate Change Adaptation Research).

Victorian Environmental Assessment Council (VEAC). (2011). *Metropolitan Melbourne investigation* (Final Report). Victorian State Government, Australia. Retrieved from: http://www.veac.vic.gov.au/reports/Discussion%20Paper%20-%20Full%20Report%20MMI.pdf

Copenhagen, Denmark

Revealing Sprawl and Structural Connectivity in Europe: A Cross-National Comparison

Menno Mandemaker, Martha Bakker and Tom (A.) Veldkamp

Environmental challenges posed by sprawl resulting from urban development, industry and infrastructure are still largely ignored at the European level (EEA, 2006). Although the European Spatial Development Perspective (ESDP) recommends combatting sprawl, whether and how to do so is left to individual countries. Many (sub)national studies have been conducted on sprawl and its well-known relationship to inefficient zoning, however, little cross-national knowledge exists of how well countries have responded to the challenge of preventing it. Therefore, a significant knowledge gap exists between the national and European level despite the fact that urban development and its impacts are amongst the most important anthropogenic drivers of global environmental change (Seto et al., 2012). To address this knowledge gap, we present a comprehensive overview of how 19 European countries have responded to increasing artificial land cover in order to prevent sprawl (observed at the national level), and how well they responded (relative to one another), for 1990 – 2006.

It is estimated that circa 80% of the European population will live in cities by the year 2020, compared to circa 75% at present, requiring millions of new dwellings, further industrialization and new infrastructure (EEA, 2006). Sprawl resulting from this development may cause a greater decrease in structural ecological connectivity than is necessary. By structural connectivity we mean the degree to which species are geographically facilitated — or impeded — to disperse or migrate into other habitats (EEA, 2011; Tischendorf & Fahrig, 2000). Current rates of decline of structural connectivity of European landscapes pose a major threat to the survival of species that critically depend on their ability to disperse or migrate, and hence to biodiversity (EEA, 2011). Therefore, sprawl constitutes a potential threat to the survival of such species. To assess where structural connectivity is likely to have become most prone to the impact of sprawl, we present a characterization of structural connectivity. Furthermore, we combine this characterization with a comprehensive overview to address the knowledge gap of sprawl.

Sprawl and structural connectivity indicators

The 1990 and 2006 CORINE European land-cover databases are comparable inventories of 44 land-cover classes[1], which could be used at a resolution of 250m (EEA, 2012a and 2012b). We overlaid a shape file of 19 European countries[2] on the 1990 and 2006 CORINE land-cover maps in ArcGIS version 10.1. We produced two reclassifications for each country, to analyze relative changes in artificial and natural land cover. To analyze relative changes in artificial land cover, all land-cover classes from '1.1.1. — Continuous Urban Fabric' to '1.4.2. — Sports & Leisure Facilities' were defined as artificial. All other land-cover classes were defined as non-artificial. We computed Moran's *I*'s of artificial land-cover patterns for each country, by using contiguity-based spatial-weights matrices in GeoDa version 1.2.0. Contiguity terms of order higher than one did not contribute (not shown). We computed relative changes in artificial land cover (δ_{Art})- and Moran's I ($\delta_{I_{Art}}$) of artificial land-cover patterns for each country:

$$\delta_{Art} \equiv \frac{Art\,(2006)\text{-}Art\,(1990)}{Art(1990)} \qquad (1)$$

$$\delta I_{Art} \equiv \frac{I_{Art}\,(2006)\text{-}I_{Art}\,(1990)}{I_{Art}\,(1990)} \qquad (2)$$

In Eq. 1, *Art*(1990) and *Art*(2006) are areas of artificial land cover in 1990 and 2006, respectively. In Eq. 2, I_{Art}(1990) and I_{Art}(2006) are Moran's *I*'s of artificial land-cover patterns in 1990 and 2006, respectively. We defined the following sprawl indicator (*S*):

$$S \equiv \frac{\delta I_{Art}}{\delta_{Art}} \qquad (3)$$

In Eq. 3, $\delta_{I_{Art}}$ is relative change in Moran's I of an artificial land-cover pattern (Eq. 2), and δ_{Art} is relative change in area of artificial land cover Art (Eq. 1).

To analyze relative changes in natural land cover, all land-cover classes from '3.1.1. — Broad-leaved Forest' to '3.2.4. — Transitional Wood-land Shrubs', and '3.3.3. Sparsely Vegetated Areas' were defined as nature. All other land-cover classes were defined as non-nature. We estimated relative changes in average patch area of nature (δ_{A_P}) and nature (δ_N) for each country:

$$\delta_{A_P} \equiv \frac{A_P\,(2006)\text{-}A_P\,(1990)}{A_P\,(1990)} \qquad (4)$$

$$\delta_N \equiv \frac{N(2006)\text{-}N(1990)}{N(1990)} \qquad (5)$$

In Eq. 4, A_p(1990) and A_p(2006) are estimates of average patch areas of nature in 1990 and 2006, respectively. In Eq. 5, N(1990) and N(2006) are estimated areas of nature in 1990 and 2006, respectively. Note that A_p is merely a pattern metric, and not an indicator of structural connectivity. However, whenever nature increases or decreases in a given area, structural connectivity of that area also increases or decreases, respectively (Jaeger et al., 2008). Therefore, δ_N could be used as indicator of relative change in structural connectivity.

Many (sub)national studies have been conducted on sprawl and its well-known relationship to inefficient zoning, however, little cross-national knowledge exists of how well countries have responded to the challenge of preventing it.

Sprawl performance and characterization of structural connectivity

All 19 countries increased their artificial land cover during 1990 — 2006. The more positive sprawl indicator *S* for a country, the less artificial land cover was allowed to increase in a random and uncoordinated fashion (relative to other countries); effectively better preventing sprawl (see Figure 1).

Combining estimated relative changes in average patch area δ_{A_P}(Eq. 4) and nature δ_N(Eq. 5) of each country, we constructed a characterization of European structural connectivity for 1990 — 2006. We illustrated this characterization in Figure 2A, and we applied it onto empirical data in Figure 2B. We constructed bar charts of ranked sprawl indicator *S* (see Figure 3). Figures 2B and 3 were produced in R version 2.15.

1 CORINE land-cover classes: http://ec.europa.eu/agriculture/publi/landscape/about.htm

2 Abbreviations of countries: AU = Austria, BU = Bulgaria, BX = Belgium-Luxembourg, CZ = Czech Republic, DK = Denmark, ES = Estonia, FR = France, GE = Germany, HU = Hungary, IL = Ireland, IT = Italy, LA = Latvia, LI = Lithuania, NL = the Netherlands, PL = Poland, PO = Portugal, RO = Romania, SL = Slovenia, and SP = Spain. Belgium and Luxembourg were merged into Belgium-Luxembourg (BX) for technical reasons.

Figure 1 | Geographical representation of countries and sprawl indicator *S* for 1990 – 2006 (produced in ArcGIS version 10.1); the more green — red, the higher — lower sprawl indicator *S* (white indicates no data). See Footnote 2 for the list of country abbreviations.

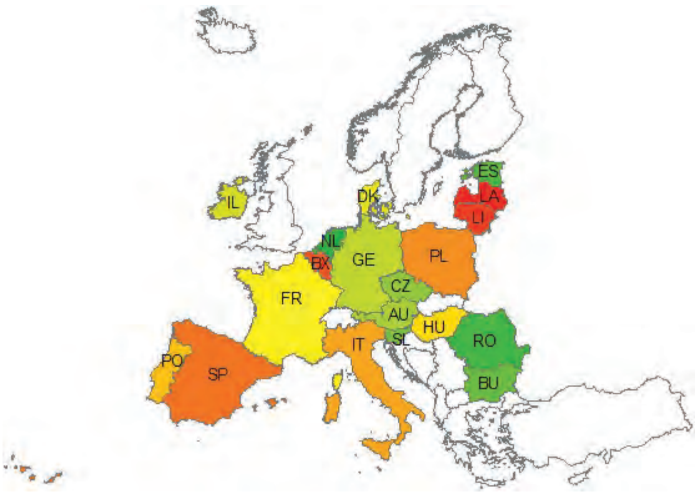
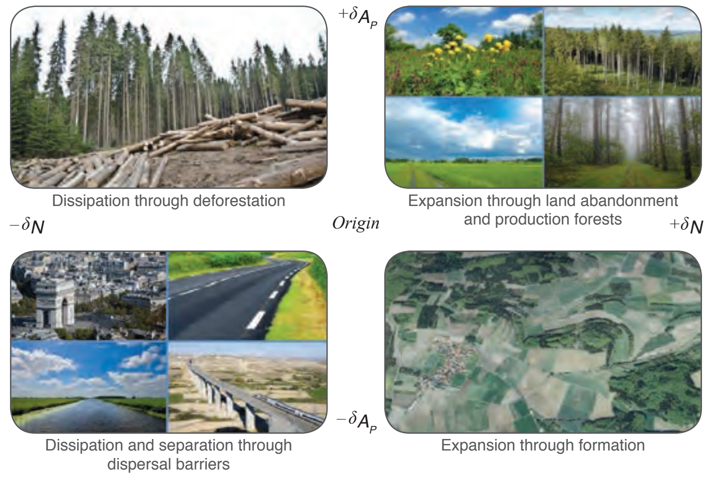


Figure 2A | Illustration of characterization of European structural connectivity of nature for 1990 – 2006, with relative change in average patch area δA_P on the y-axis, and relative change in structural connectivity δN on the x-axis.



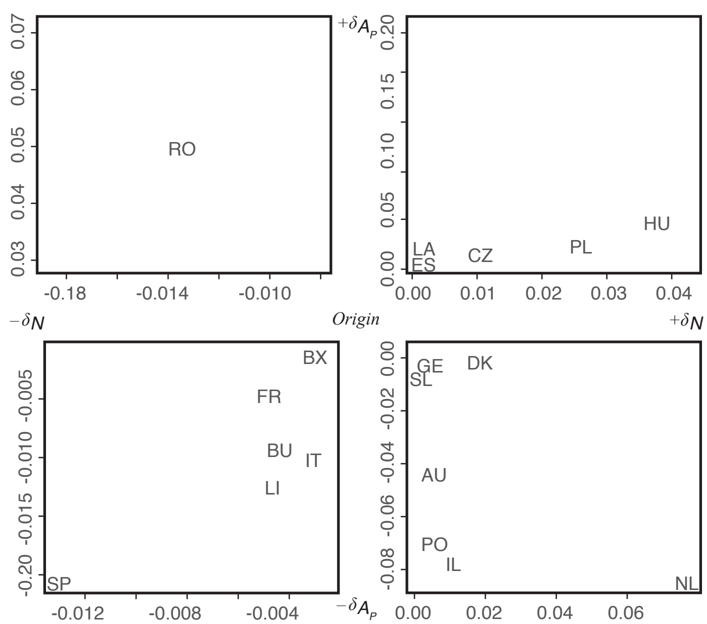
Source: Depositphotos www.depositphotos.com; Lower-right quadrant (near Burggrub, Germany), Google Earth

In the lower-left quadrant, structural connectivity likely decreased more through dissipation and/or separation of nature by artificial land cover (see Figure 2A). That is, through dispersal barriers that either dissipated surface area (e.g., urban areas and industry) or separated entire areas of nature that were previously connected (e.g., infrastructure, waterways, and fences). In the upper-left quadrant, structural connectivity likely decreased more through dissipation of nature by deforestation. Furthermore, in the upper-right quadrant, structural connectivity likely increased more through expansion of nature by farmland abandonment- and/or growing of production forests. While in the lower-right quadrant, structural connectivity likely increased more through expansion of nature by formation. That is, by formation of new patches and/or corridors of nature.

Discussion

Sprawl indicator *S* divided countries into three categories for 1990 – 2006, broadly commensurate with restrictiveness of zoning policy in each category: unrestrictive policy ($S<0$), moderately-restrictive policy ($0<S<1$), and highly-restrictive policy ($S>1$). Belgium-Luxembourg, Italy, Lithuania, and Spain responded particularly unrestrictive to increasing artificial land cover ($S<0$). These countries did not prevent sprawl, but caused it instead. Their structural connectivity decreased, likely more due to dispersal barriers. Of these countries, Belgium-Luxembourg had the highest level of fragmentation, i.e., most impacted by sprawl, followed by Lithuania.

Figure 2B | Characterization of European structural connectivity of nature for 1990 – 2006, with relative change in average patch area δA_P on the y-axis, and relative change in structural connectivity δN on the x-axis. See Footnote 2 for country abbreviations.



Latvia and Poland also responded particularly unrestrictive to increasing artificial land cover ($S<0$). While their structural connectivity increased, this is more likely due to farmland abandonment (Hobbs & Cramer, 2007). However, these increases may be overestimated due to production forests that were detected

Figure 3 | Bar charts of ranked sprawl indicator *S* for the lower-left, upper-left, upper-right, and lower-right quadrant of the characterization of structural connectivity for 1990 – 2006. See Footnote 2 for country abbreviations.

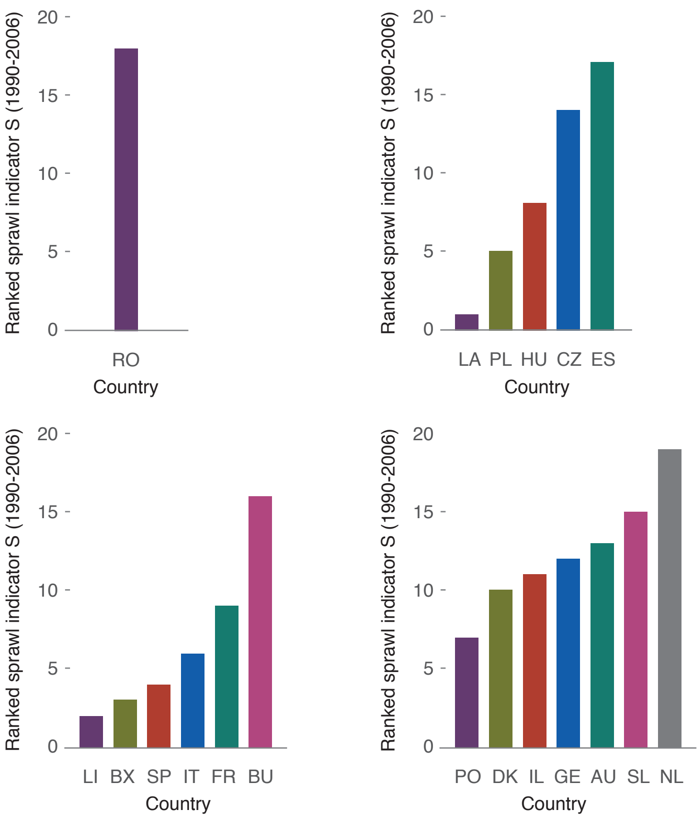
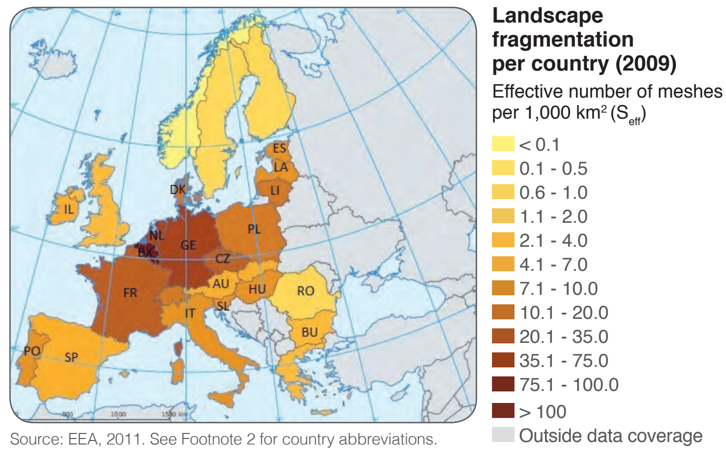


Figure 4 | Landscape fragmentation in Europe (effective mesh density).



Source: EEA, 2011. See Footnote 2 for country abbreviations.

as nature (Eurostat, 2012). Post-socialist farmland abandonment was commensurate with major migration from rural to urban areas in the 1990s (EEA, 2006), causing an increase in dispersal barriers (i.e., urban areas, industrialization, and infrastructure). Of these countries, Poland had the highest level of fragmentation, meaning that out of these countries its structural connectivity is likely to have been more impacted by sprawl. Latvia responded most unrestrictive to increasing artificial land cover and seems to be going in the same direction as Poland.

France, Hungary, and Portugal were practically unresponsive to increasing artificial land cover ($S \approx 0$), which is worrying. Structural connectivity decreased in France, more likely due to dispersal barriers. While it likely increased more by farmland abandonment in Hungary, production forests that were detected as nature may again have caused an overestimate in this case (Eurostat, 2012; Hobbs & Cramer, 2007). This overestimate may also be present in Portugal - although its structural connectivity increased and is in the 'Expansion through formation' quadrant, considerable land abandonment occurred as well (EEA, 2010; Eurostat, 2012). Of these countries, France is likely to have been more affected by sprawl, as it had the highest level of fragmentation, while Hungary and Portugal had lower and similar levels of fragmentation.

Bulgaria and Romania responded moderately restrictive to increasing artificial land cover ($0<S<1$). While their structural connectivity decreased, this is more likely due to dispersal barriers and deforestation, respectively. Of these countries, Bulgaria had the highest level of fragmentation. Austria, the Czech Republic, Denmark, Estonia, Germany, Ireland, and Slovenia also responded moderately restrictive to increasing artificial land cover ($0<S<1$), while their structural connectivity increased. That is, it likely increased more by formation of new patches and/or corridors of nature in Austria, Denmark, Germany, Ireland, and Slovenia, and by more farmland abandonment in the Czech Republic and Estonia. Structural connectivity increases in Austria, the Czech Republic, Estonia, and Germany may again be attributed to an overestimate with respect to production forests (Eurostat, 2012). Major migration from rural to urban areas occurred in the Czech Republic, Estonia, and Slovenia, and farmland abandonment also occurred in Slovenia (EEA, 2006; Hobbs & Cramer, 2007). Moreover, land-use policy and land cover in these countries are still greatly affected by lingering political influences (originating from the communist era). For example, most Central and Eastern European Countries (CEECs) are still struggling with the implementation of major land reforms to return previously collectivized agricultural land to private owners (Stanilov, 2007). Overall, it is less likely that formation of new patches and/or corridors of nature significantly contributed to structural-connectivity increases in these countries, compared to Austria, Denmark, Germany, Ireland, and the Netherlands. In the latter countries, formation of new patches and/or corridors of nature are most likely to have contributed to structural connectivity increases (EEA, 2011). The Netherlands responded highly restrictive to increasing artificial land cover (S>1). Moreover, its structural connectivity increased most of all countries. However, of these countries, the Netherlands also has the highest level of fragmentation, together with Germany.

Implications for policy

Results clearly indicate that the challenges posed by sprawl and landscape fragmentation need to be addressed in a more coordinated way. Urban development is locally regulated without directives at the European Union (EU) level, while investment in EU funds (i.e., the 'Structural' and 'Cohesion' funds) devoted to regional urban development policy remains key to support sprawl prevention (EC, 2013b; EEA, 2006). Moreover, for likely reasons of institutional complexity, and because sprawl is not sufficiently recognized as a serious issue, it is not explicitly included in criteria of eligibility for EU funding of regional urban development. As a result, regional authorities are not obliged to include sprawl-prevention policies in their strategies of urban development to be eligible for funding. EU policy responsible for funding of regional development during the period 2007 – 2013 (i.e., the so-called 'Cohesion' policies), treated issues of sustainability and urban development in a way that was insufficiently integrated. This was further complicated by the fact that EU intervention in many other policy domains affects (or is affected by) urban development (EEA, 2006). New 'Cohesion' policies for regional urban development have recently been proposed for the period 2014 – 2020 to support the required development of industry and millions of new dwellings during this period (EC, 2013b; EEA, 2006), and to support the establishment of the Trans-European Transport Network (TEN-T), which requires the construction of many thousands of kilometers of new infrastructure (EC, 2013a).

To contain sprawl and structural-connectivity decreases resulting from these future developments, issues of coordination and integration must be resolved. Ways forward to achieving this include increasing policy coherence, heightening responsiveness to local conditions, and strengthening cooperation in policy development – known as principles of good governance (EEA, 2006). Increasing policy coherence would help ensure that decisions taken at local and regional levels are coherent with EU policy. Heightening responsiveness to local conditions would help ensure support of (and flexibility and sensitivity towards) local initiatives and priorities. Strengthening cooperation in policy development would help ensure that local and regional knowledge and conditions are taken into account at the EU level when developing policy proposals (EEA, 2006). Achieving these goals could allow for further cross-scale institutionalization, and thus for further cross-scale operationalization of proposed legislation and policies (EC, 2013b). Such multi-level governance obtained through institutional learning could allow for better coordination and integrated policies to prevent sprawl and fragmentation. However, the EU should also put these two issues higher on the agenda and play a more active role in communication and facilitation. For example, it could do much more in terms of engaging local, regional, and national authorities to establish trilateral agreements that could work to prevent sprawl and fragmentation (EEA, 2006).

References

European Commission (EC). (2013a). *Transport infrastructures - TEN-T*. Retrieved from: http://ec.europa.eu/transport/themes/infrastructure/index_en.htm

European Commission (EC). (2013b). *EU Cohesion Policy 2014-2020: Legislative proposals.* Retrieved from: http://ec.europa.eu/regional_policy/what/future/proposals_2014_2020_en.cfm

European Environment Agency (EEA). (2006). *Urban sprawl in Europe: The ignored challenge* (EEA Report No. 10). Copenhagen, Denmark: EEA. Retrieved from: http://www.eea.europa.eu/publications/eea_report_2006_10

European Environment Agency (EEA). (2010). *Land use: Portugal*. Retrieved from: http://www.eea.europa.eu/soer/countries/pt/soertopic_view?topic=land

European Environment Agency (EEA). (2011). *Landscape fragmentation in Europe* (EEA Report No. 2). Copenhagen, Denmark: EEA. Retrieved from: http://www.eea.europa.eu/publications/landscape-fragmentation-in-europe

European Environment Agency (EEA). (2012a). *CORINE 1990 land-cover database*. Retrieved from: http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-1990-clc1990-and-corine-land-cover-changes-1975-1990-in-a-10-km-zone-around-the-coast-of-europe

European Environment Agency (EEA). (2012b). *CORINE 2006 land-cover database*. Retrieved from: http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster-1

Eurostat. (2012). *Forestry statistics.* Retrieved from: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Forestry_statistics

Hobbs, R. J., & Cramer, V.A. (2007). *Old fields: Dynamics and restoration of abandoned farmland.* Washington, D.C.: Island Press.

Jaeger, J. A., Bertiller, R., Schwick, C., Müller, K., Steinmeier, C., Ewald, K. C., & Ghazoul, J. (2008). Implementing landscape fragmentation as an indicator in the Swiss Monitoring System of Sustainable Development (MONET). *Journal of Environmental Management, (88)*4, 737-751.

Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *PNAS (Proceedings of the National Academy of Sciences of the United States of America), 109*(40), 16083-16088.

Stanilov, K. (2007). Urban development policies in Central and Eastern Europe during the transition period and their impact on urban form. In K. Stanilov (Ed.), *The post-Socialist city: Urban form and space transformations in Central and Eastern Europe after Socialism* (pp. 347-359). Dordrecht, The Netherlands: Springer.

Tischendorf, L., & Fahrig, L. (2000). On the usage and measurement of landscape connectivity. *Oikos, 90,* 7-19.

Bangkok street trees

Street Tree Management in Bangkok, Thailand: Policies, Challenges and Perceptions of Ecosystem Services

Natthanij Soonsawad

Ecosystem services are recognized by the international scientific community as important resources within cities and for offering opportunities for sustainable development (Bolund & Hunhammar, 1999; Millennium Ecosystem Assessment, 2003). This is particularly significant in developing countries where rapid and unbalanced urbanization often occurs, thereby reducing green space (Kong & Nakagoshi, 2005; Pham & Nakagoshi, 2007; Byomkesh et al., 2012) and thus the provision of ecosystem services. One approach to protect ecosystem services is through appropriate institutional mechanisms (Daily, 2000), but there is a dearth of data on the acknowledgement and perception of these services by public officials in cities of the developing world. Research shows that ecosystem services are useful in addressing a number of urban and environmental problems, particularly through landscape management policies, and should be acknowledged by policy makers, public officials, and citizens alike. This is not only to avoid the loss of some services, but to also aid in their maintenance and conservation (Daily, 2000; Costanza et al., 2006), including the promotion of habitat preservation and policy objectives that are often overlooked (Salzman et al., 2001).

This paper investigates policy issues and challenges with respect to street tree planting and maintenance in Bangkok, Thailand and evaluates the perceptions held by public officials on the ecosystem services provided by street trees. In 2012, I interviewed 25 district agricultural officials in 25 districts of Bangkok[1] and constructed a perception index to measure the level of understanding among them. This is part of a larger project researching the benefits of ecosystem services within the city.

Street tree management and policy overview

Green spaces are areas that are partly or completely covered with grass, shrubs, trees, or other vegetation. Tree planting in the communities is recommended over shrubs or ornamental plants

1 There are total of 50 districts in the city of Bangkok. Each has agricultural officials responsible for tree management. 50% of them were surveyed, accounting for areas that cover 65% of the city.

Electrical wiring conflicts with street trees

Challenges to tree development caused by vendor equipment/cart storage

due to low maintenance, long lifespan, and high tolerance (Forest Research Center, 2004). As most of the areas in Bangkok are developed lands (Forest Research Center, 2003), street trees are greatly needed to provide ecosystem services such as reducing air, water and noise pollution, regulating temperature and providing recreational benefits (Bolund & Hunhammar, 1999). A complete street tree inventory in Bangkok was first conducted in 2000. The total street tree population was nearly 200,000 and included 127 species with 42% of *Pterocarpus indicus* or Narra (Thaiusa et al., 2008). Planting and re-planting decisions are heavily influenced by the existing species configuration of trees in each street without due consideration of alternative species that exhibit broader ecosystem services or lower maintenance costs. Currently, new urban infrastructure construction (e.g., condominiums, roads, housing estates, and sky trains) has affected the number of street trees as the city is continuously expanding. Public street trees also have other challenges to contend with, which are discussed here below.

Relevant guidelines and policies on street tree enhancement in Bangkok are derived mainly from two documents, 'The Master Plan of Bangkok Green Area' and 'Sustainable Measures to Enhance and Manage Green Spaces in the Communities'. The Master Plan aims to increase the size of green space to meet the international standard of green space per capita (9m^2 per capita) especially in the form of parks or accessible public green spaces for recreation including street tree gardens, or riverside gardens.

It also provides the action and implementation plan for the city government or Bangkok Metropolitan Administration (BMA) and offers guidelines on how to seek out more green spaces. For example, it suggests that the BMA request assistance from the business sector, governmental agencies, schools or temples to increase the number of green spaces in their areas, such as areas between buildings or street setbacks (Forest Research Center, 2003). The latter document provides guidelines for implementing laws and economic instruments for maintaining or enhancing a number of green spaces, criteria in selecting appropriate tree species for planting on the streets as well as listing examples from other cities abroad as good models of practice for Bangkok (Forest Research Center, 2004).

All districts within the city have public campaigns and activities promoting tree planting, some of which include giving plant saplings and seedlings at no cost to residents, schools, or private companies during various national holidays so that everyone can have the opportunity to be involved in the activities. Unfortunately, however, there are no policies specifically promoting ecosystem services from trees.

A better understanding amongst city officials and the general public in Bangkok of the importance of street trees, particularly with respect to their capacity to provide ecosystem services, could help mitigate some of the issues that affect the population and health of city trees.

Challenges in street tree management

Major challenges in management include the lack of personnel to provide adequate maintenance, issues in tree health and maintenance and the conflicts that occur through arbitrary tree removal and damages. There are also resident complaints from damages by street trees.

More than 50% of districts face insufficient labor for the maintenance of trees. An insufficient budget and untrained crews are also management problems. There are also mismanagement issues. For example, only top-down management approaches exist in some districts, resulting often in the failure by supervisors to listen to subordinates' concerns or problems they've encountered on the ground.

The health of trees brings other challenges, although most districts (84%) have a higher proportion of healthy trees than unhealthy trees. The causes of unhealthy trees can include pests, brittle branches, eroded roots, root interference with underground pipelines, or intolerance in younger trees. Also, some trees are extremely old and are deteriorating as a result of natural aging. The major problem of the most dominant species, *Pterocarpus indicus* (Narra) in the city is that it is prone

Table 1 | Score of public officials' understanding of ecosystem service benefits (1= providing a superficial response, 7 = providing a well-informed response)

	Number of Public Officials									
Score	1	2	3	4	5	6	7	Total Score	Average Score	Standard Deviation
Economic Benefits	11	0	3	3	2	5	0	72	3	2.09
Environmental Benefits	0	0	5	6	3	3	7	121	5.04	1.57
Social Benefits	0	0	3	3	3	10	5	131	5.46	1.32

Table 2 | 25 agricultural officers' perceptions of the ecosystem service benefits provided by street trees

Economic Benefits	Percentage	Environmental Benefits	Percentage	Social Benefits	Percentage
Providing materials to be used in fertilizers (cut branches or fruits)	20.83	Reducing air pollution	91.67	Providing recreational space/meeting places	66.67
Reducing the electricity cost from air conditioners	12.50	Reducing the temperature	33.33	Providing shade to pedestrians	54.17
Providing materials for making furniture (dead trees)	12.50	Reducing noise pollution	29.17	Providing aesthetic pleasure and relief from stress	48.33
Providing materials for making charcoal (dead trees)	8.33	Providing oxygen	25.00	Improving physical health	25.00
Helping to add value to the property	4.17	Reducing stormwater runoff	12.50	Enhancing street safety for pedestrians	8.33
Saving money for food costs	4.17	Sequestering CO_2	8.33	Enhancing street safety for drivers	8.33
Providing jobs to people who grow trees	4.17	Enhancing soil quality	4.17	Providing food for the community	8.33
Gaining carbon credits for tree planting	4.17	Preventing soil erosion	4.17	Reducing crime	4.17

to stem borers, *Aristobia horridula*, a type of beetle. Additionally, the position of water pipelines, poor soil quality and shallow soil layers in some planting strips impede the root growth underground. Some districts have insufficient water sources, resulting in unhealthy trees.

Around 80% of the observed districts have experienced conflicts, especially with street vendors (both mobile and fixed vendors) mostly in inner Bangkok, as some vendors illegally cut or damage trees at nighttime or indirectly damage them through the use of equipment storage or food waste disposal. Another source of conflict includes damage to property. About 70% of districts experienced complaints filed by residents due to residential property and car damage. In most cases, the districts compromise and provide compensation. Species that cause damages to properties by broken-off branches are *Pterocarpus indicus* (Narra), *Delonix regia* (Royal poinciana), *Tabebuia rosea* (Pink trumpet tree) and *Peltophorum pterocarpum* (Yellow flame tree). Damage to sidewalks is mostly caused by roots of *Tabebuia rosea* and *Alstonia scholaris* (Blackboard tree). Furthermore, aboveground phone and electrical wires interfere with tree branches, requiring regular tree pruning to control the weight and volume of the canopy as well as to minimize contact with the wires.

Perceptions of ecosystem services provided by street trees

Building a better understanding of the ecosystem services provided by street trees is particularly necessary for those persons responsible for associated policy implementation and their enhancement in Bangkok. It is also important to raise awareness about the importance of ecosystem services provided by trees amongst the general public. To illustrate this, I constructed a perception index using the scale from 1-7 to measure public officials' understanding of ecosystem services from street trees. I conducted interviews with public officials in districts of the city that are characterized by varied types of land use and levels of urbanization. A high value of seven was given to a well-informed response, and a value of one was given to a highly superficial response. The scores and the response information provided by public officials are listed in Table 1 and 2 respectively.

An analysis of these results indicates that the interviewed public officials understand fairly well the *social benefits* of trees (scored 5.46), but have a low level of understanding of their *economic benefits* (scored 3.00). Among the information given on each benefit category (see Table 2), the officials gave the least on economic benefits. Only about 21% of officials recognized that tree branches from pruning could be used as fertilizer. For the environmental benefits of street trees, most of the public officials (91.67 %) mentioned they were aware trees help reduce air pollution, but they did not elaborate in any further detail. The most common social benefit mentioned during the interviews was the provision of recreational amenities, followed by provision of shade for pedestrians (66.67 % and 54.17 % respectively).

Despite the fact that there are no campaigns currently promoting the ecosystem services provided by street trees, the majority of district officers felt that these would be important and should be implemented in the future, particularly to aid in selecting appropriate species for new planning projects and assist in their overall maintenance. However, they also recognized difficulties reaching out to some groups, especially in residential zones, due to occasional unwillingness to be involved, and that there are insufficient human resources to implement such campaigns.

Implications for future policy

As identified in the interviews, the recommended tree species included those requiring low maintenance, having evergreen foliage, and appropriate canopy density such as *Swietenia macrophylla* (Big-leaf mahogany). Trees with hairy leaf surfaces were also highly recommended, as it allows for the interception and filtration of particulate matter in the air such as ones in genus *Lagerstroemia* (Crape myrtles). Two districts recommended food-bearing street trees such as *Dolichandrone serrulata, Azadirachta indica* (Neem or Indian lilac), and *Senna siamea* (Kassod tree). They also indicated a preference towards trees that are easy to prune into well-balanced canopies, that are safe for pedestrians and drivers, and that avoid interfering with utility wires.

A better understanding amongst city officials and the general public in Bangkok of the importance of street trees, particularly with respect to their capacity to provide ecosystem services, could help mitigate some of the issues that affect the population and health of city trees (e.g., challenges in tree management or conflicts that arise between residents and the city). It is crucial to promote educational policies to further the understanding of the variety of ecosystem services provided by street trees and to create meaningful public participation in the maintenance and conservation of those services. Outreach programs and awareness campaigns could lead to changes in behaviors among urban actors and consequently improve the quality of life in cities. This should be undertaken in a timely manner especially in the inner core of Bangkok where environmental degradation and conflicts between the city and residents are concentrated.

Moreover, the allocation of city resources for tree planting and maintenance should be defined through participatory mechanisms that involve the recommendations from those directly involved in tree management. Bottom-up management can lead to a better understanding of the amount of work, challenges and limitations experienced on the ground to maintain healthy public trees. Additionally, it is necessary to develop an assessment of the available public space in the city to implement adequate planting strategies that improve city aesthetics, tree conditions and increase the environmental benefits from public urban forests. The cooperation of residents with governmental agencies to promote green spaces and street trees will enhance the opportunities to build a sustainable urban development process in the city.

References

Bolund, P., & Hunhammar, S. (1999). Ecosystem services in urban areas. *Ecological Economics, 29*(2), 293-301.

Byomkesh, T., Nakagoshi, N., & Dewan, A. M. (2012). Urbanization and green space dynamics in Greater Dhaka, Bangladesh. *Landscape and Ecological Engineering, 8*(1), 45-48.

Costanza, R., Wilson, M., Troy, A., Voinov, A., Liu, S., & D'Agostino, J. (2006). *The value of New Jersey's ecosystem services and natural capital.* Burlington, VT: Gund Institute for Ecological Economics, University of Vermont. Retrieved from: http://training.fws.gov/EC/Resources/nrdar/injury_quantification/NJvaluationpart2.pdf

Daily, G. C. (2000). Management objectives for the protection of ecosystem services. *Environmental Science and Policy, 3*(6), 333-339.

Forest Research Center. (2003). *Executive summary: The master plan of Bangkok green area.* Bangkok, Thailand: Forest Research Center, Department of Forestry, Kasetsart University.

Forest Research Center. (2004). *Full report: Sustainable measures to enhance and manage green spaces in the communities.* Bangkok, Thailand: Forest Research Center, Department of Forestry, Kasetsart University.

Kong, F., & Nakagoshi, N. (2005). Change of urban green spaces and their driving forces: a case study of Jinan City, China. *Journal of International Development and Cooperation, 11*(2), 97-109.

Millennium Ecosystem Assessment. (2003). *Ecosystems and human well-being: A framework for assessment.* Washington, D.C.: Island Press.

Pham, D., & Nakagoshi, N. (2007). Analyzing urban green space pattern and eco-network in Hanoi, Vietnam. *Landscape and Ecological Engineering, 3*(2), 143-157.

Salzman, J., Thompson Jr., B. H., & Daily, G. C. (2001). Protecting ecosystem services: science, economics and law. *Stanford Environmental Law Journal, 20,* 309-332. Retrieved from: http://scholarship.law.duke.edu/cgi/viewcontent.cgi?article=1881&context=faculty_scholarship

Thaiutsa, B., Puangchit, L., Kjelgren, R., & Arunpraparut, W. (2008). Urban greenspace, street tree and heritage large tree assessment in Bangkok, Thailand. *Urban Forestry & Urban Greening, 7*(3), 219-229.

Bahariya Oasis, Egypt

Spatial Analysis of Oases Transformation for Sustainable Growth in El-Bahariya Oasis, Egypt

Ahmed Abdelhalim M. Hassan

In the last decade, sustainable growth and development have become of paramount importance, especially in cities of developing countries where the misuse of land and loss of natural resources have been extensive. Land and environmental degradation, however, varies across and often within urban areas. It is influenced by population density and pace of urbanization. Particularly in arid areas, where resources are already scarce, innovative adaptation strategies are essential for reducing vulnerability to global environmental change impacts that will place further strain on the availability of resources. For example, the over-populated Delta region in Egypt is suffering from food scarcity and drought which is complicated further by the negative impacts of sea level-rise, desertification in some parts and flooding in others. Although there is uncertainty regarding the degree to which the negative effects of environmental changes will affect land and other resources, there is an urgent need to take current environmental degradation very seriously.

Future development needs to incorporate adaptation strategies that are sensitive to these changing environments. In this light, this research investigates the opportunities that exist within the El-Bahariya Oasis, which is a low-density area that could be a model for sustainable growth in the region. El-Bahariya Oasis is located in the central part of the Western Egyptian Desert, and is linked to Greater Cairo Metropolis by a highway of approximately 360km (see Figure 1). Historically, the El-Bahariya Oasis has been dominated by different driving forces such as farming, archaeological research, mining activity, manufactured goods, and is recently a target for renewable energy projects. I introduce here the idea of an 'incubation strategy' which could be implemented to attract segments of the population to push the oasis transformation and help establish the nucleus of an eco-city. This would not only lead to improved life quality, but will altogether have positive effects on the global environment and climate.

Time of transformation

Nowadays, we are living in an era of transformation that requires an understanding of the global environment based on knowledge from the natural and social sciences, economics and also politics. Cumming et al. (2005) defined a resilient social-ecological system as consisting of essential actors, components, and interaction where the system's identity consists of maintaining these elements through space and time. Vulnerability of systems has been referred to as the susceptibility to harm from exposure to stress associated with environmental and social change (Adger, 2006). Only until recently, have researchers focused on management schemes that take a systems approach to understanding ecosystems and for new strategies for sustainability, which include social parameters. This development in scientific thinking is reflected by the need to understand complex issues such as urban growth and the bidirectional interactions with global environmental changes, particularly in the developing world.

Moreover, the global economic crisis of 2008 has been driving economic institutions all over the world to rethink the current economic system in a way that would be able to solve the social challenges characterized by increasing modernity alongside increasing poverty. In Egypt, degradation of the environment and natural resources, in addition to the increase in the rate of population growth has led to dramatic changes in society and underlined the recent 2011 revolution in the country.

Figure 1 | Location map of the El-Bahariya Oasis study area

Source: Modified from Google Maps

> Analysis and understanding of oases dynamics including urbanization patterns, human activities, natural resources, fertile land, etc., and their interactions are complex and require sophisticated tools for designing environmental management approaches, especially in developing cities.

Key elements for sustainability and transformation

Analysis and understanding of oases functions such as urbanization patterns, natural resources, human activities, fertile land, etc., and their interactions are complex and require sophisticated tools for designing environmental management approaches, especially in developing cities. This is of major importance for Egypt, as the country has no clear strategy for urbanization which has led to random and uncontrolled development of oases. In order to develop and sustainably transform such complex systems and to integrate and manage the relationships between processes, an effective conceptual model and tools to support the management of ecosystems are needed.

I use a socio-ecological conceptual model to understand the El-Bahariya Oasis system and develop environmental indicators to monitor the oasis transformation. The determination of indicators is an excellent way of representing environmental components avoiding the measurement of too many parameters (Mourão et al., 2004). These indicators will be monitored and analysed by using multi-temporal-resolution satellite data and applying advanced remote sensing classification techniques, which are then integrated with a geographic information system (GIS) to produce landscape information based on knowledge integration.

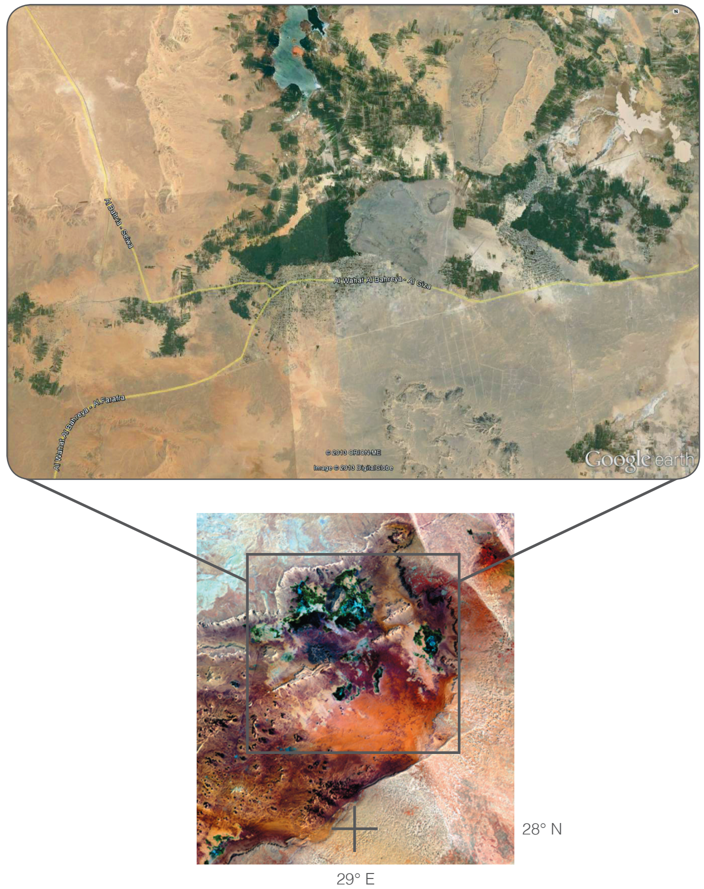
The 'Driving forces, Pressure, State, Impact, and Response (DPSIR) model' is a causal framework for describing the interactions between society and environment, developed by the Organization for Economic Co-operation and Development (OECD). In this study, the DPSIR model is used to identify and to determine the development indicators of the oasis in relation

Figure 2 | DPSIR schehme

Driving Forces	Development and investments	**Human Activity**
	Green cover	
	Population growth	
	Land change	
Pressures	Rapid urbanization	
	Use of fertile land	
	Industry	
States	Controlled and uncontrolled settlements	
	Dynamic expansion of the city	
	Decline of agricultural fields and green cover	
	Landscape degradation and loss of protected areas	
Impacts	Diversity of quality of life	**Changes**
	Soil and fertile land loss	
	Development of informal activities	
	Water body changes	
Responses	Improvements in environmental planning and management	
	Suitable policies and strategies	

Source: Hassan (2013)

Figure 3 | Classified area of El-Bahariya



Source: TM Landsat and Google Maps

to ecology and the society, and also to aid in the identification of the main transformation indicators. Accordingly, the relationship between natural resources, human activities (society) and the dynamic processes of land use/land cover change will be better understood and ideally feed into policies and sustainable management plans (see Figure 2).

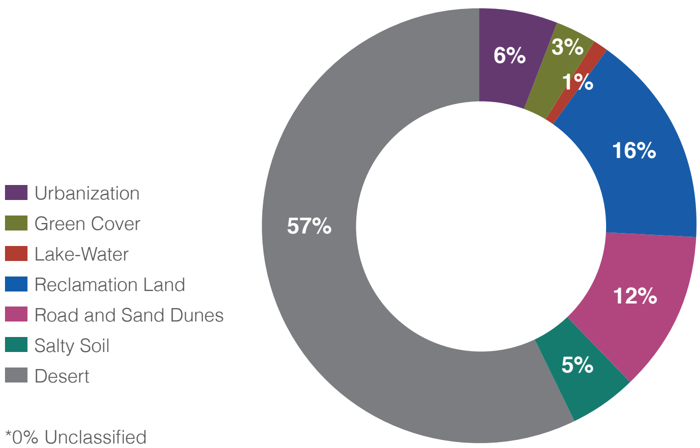
A familiarity with the geographical setting will help to evaluate the natural resources and land suitability. The main land use/land cover (LULC) classifications that were examined in El-Bahariya Oasis include: urbanization, green cover, reclamation land, surface water, desert (hinterland), roads-dunes, and bare-salty soil (see Figure 3 and 4). These classes provide a practical means for determining the dynamic changes in spatial resilience to achieve management objectives, and they can also be used to predict future changes and to assess development challenges.

Incubation strategy (development catalyst)

Incubation refers to the process by which certain oviparous animals hatch their eggs, and to the development of the embryo within the egg. This term often used in economic terms as 'business incubators', have traditionally been recognized as new organizational forms for promoting entrepreneurship and stimulating new business formation (Allen, 1985). Eshun Jr. (2009) proposed an unprecedented revolutionary change in the structure of the U.S. economy that warrants attention to internal structures, cultures and strategies. He attempted to make business incubation a strategy not only for new and emerging technology-driven firms but also for large industrialized corporations. Similarly, this study introduces this concept for planners and development aid sponsors to provide for the overpopulated delta cites in Egypt by attracting skilled people and researchers to establish an innovation system with forward-thinking socio-environmental institutions, and to generate projects, particularly in renewable energy and ecosystem conservation in oases areas.

Moreover, random migration and informal urbanization growth threatens developing areas and increases the negative impacts on the environment locally and globally (de Sherbinin et al., 2009). Recently, the ADB (2012) report warns that "if migration is not carefully planned and assisted, there is a serious risk that it can turn into maladaptation, i.e., leaves people more vulnerable to environmental changes".

Figure 4 | Chart of land use/land cover of El-Bahariya Oasis*



Thus, the environmental incubation strategy that is suggested here aims to describe a vision for oasis transformation that is developed sustainably, e.g., promotes the equitable, ethical and efficient use of natural resources (Norberg & Cumming, 2008), and monitor and evaluate the growth and development of current and new projects for the study area. This would involve the establishment of an innovation unit or ecological technology research centre that would ultimately provide decision makers and stakeholders with up-to-date data and information for effective plans and policies. Skilled staff and other collaborators and stakeholders such as employers, labours, farmers as well as the oasis Bedouin population could initiate a nucleus society which could be then further attract segments of the population to push the oasis transformation. As a result, qualitative and planned demographic change could emerge supported by sustainable work and infrastructure.

Conclusion

In this study we introduce the concept of incubation as a strategy for the El-Bahariya oasis transformation, and for controlling the demographic changes resulting from out-migration from over-populated regions carefully.

The spatial analysis provided by our methodology for El-Bahariya Oasis would be essential to:

- Assess the consequences of dynamic change and urban growth;
- Develop sustainable management of natural resources in the oasis; and
- Minimize negative impacts of population growth and climate change on quality of life.

In the future, this work will show in detail the status of planning, monitoring and implementing the current vision. Through this study the hope is to attract potential sponsors to support the ideas presented herein and assist in the practical application of the innovation system and oasis eco-city.

References

Adger, W. N. (2006). Vulnerability. *Global Environmental Change, 16*(3), 268-281.

Allen, D. (1985). *Small business incubators and enterprise development* (Report prepared for the U.S. Department of Commerce). University Park, PA: Pennsylvania State University.

Asian Development Bank (ADB). (2012). *Annual report 2011.* Mandaluyong City, Philippines: Asian Development Bank. Retrieved from: http://www.adb.org/documents/adb-annual-report-2011

Cumming, G. S., Barnes, G., Perz, S., Schmink, M., Stieving, K. E., Southworth, J., Binford, M., Holt, R. D., Stickler, C., & Van Holt, T. (2005). An exploratory framework for the empirical measurement of resilience. *Ecosystems, 8*(9), 975-987.

de Sherbinin, A., Rahman, A., Barbieri, A., Fotso, J.C., & Zhu, Y. (Eds.). (2009). *Urban population-development-environment dynamics in the developing world: Case studies and lessons learned.* Paris: CICRED.

Eshun Jr., J. P. (2009). Business incubation as strategy. *Business Strategy Series, 10*(3), 156-166.

Hassan, A. Abdelhalim. (2013). *Spatial resilience of mega cities based on conceptual model from concept to implementation, case study: Greater Cairo, Egypt.* (Paper no. 195, presented at the 18th International Conference on Urban Planning and Regional Development in the Information Society — Real CORP2013, Rome, Italy, May 20-23).

Mourão, I., Caeiro, S., Costa, M. H., Ramos, T. B., & Painho, M. (2004). Application of the DPSIR model to the Sado Estuary in a GIS context — Social and economic pressures. In F. Toppen, & P. Prastacos (Eds.), *Proceedings of the 7th Conference on Geographic Information Science* (pp. 391-402, AGILE 2004, 29 April-1 May, Crete, Greece). Crete, Greece: Crete University Press.

Norberg, J., & Cumming, G. S. (Eds.) (2008). *Complexity theory for sustainable future.* New York: Columbia University Press.

Destruction from the Great East Japan earthquake in Iwate, Japan

Green Investment in Asian Cities

Takako Wakiyama and Joni Jupesta

In recent years, large-scale natural disasters have frequently occurred in various parts of the world and the associated losses have increased (see Figure 1). As a result, there have been increasing concerns over the protective measures needed, particularly with respect to energy and infrastructure systems within cities that are also experiencing increasing risks and exposure levels. In order to avoid risks and damages, and to strengthen resilience to natural disasters, national *and* local governments need to be prepared. At the local level, authorities must take actions to construct policy packages including locally-based risk prevention facilities[1] as well as risk finance and risk transfer systems[2].

This paper identifies the risks associated with natural disasters, with particular focus on the vulnerability of energy systems. It examines the opportunities for local/community-based infrastructure to prevent risks through installing locally-based energy systems, financing mechanisms to prevent risks and risk transfer systems as well as the associated challenges that exist with respect to their establishment.

Natural disasters and risks

Natural disasters, such as the 2011 floods in Thailand, have had huge impacts on urban systems and their associated infrastructure (Chongvilaiva, 2012) (see Table 1). The nuclear power plant accident at Fukushima in Japan on March 11, 2011, a result of an earthquake and tsunami, highlighted the constraints of the existing energy system in Japan as well as its vulnerability to extreme events. Japan's energy system is very centralized and dominated by ten regional electrical companies (about 90%[3] of power generation in Japan). For example, electricity in the megacities of Tokyo and Yokohama is provided by the Tokyo Electrical Power Company, which depended on 40% (in 2010)[4] of its total generated electricity from nuclear power plants. This catastrophe increased public awareness on energy security, making it apparent that a review of energy

1 A proposal for the establishment of a risk management facility has been submitted from the Parties and other organizations to the UNFCCC. Written in the proposal is a risk management module at the international level, which consists of three tiers: an international risk pooling mechanism for developing countries; an insurance assistance facility to cover medium-level risks; and a prevention pillar to achieve risk reduction (MCII, 2008; Geneva Association, 2009).
2 In addition to governments and private enterprises that offer financial support and the provision of necessary goods and services to cover losses post-disaster, risk financing and risk transfer tools such as insurance, reinsurance, and catastrophe-linked securities are key (World Bank, 2013). Such tools help to reduce the negative economic impacts of extreme risks.
3 Agency for Natural Resources and Energy (ANRE) 2012, Energy Statistic data as of February 2013.
4 See: http://www.tepco.co.jp/en/challenge/energy/nuclear/plants-e.html

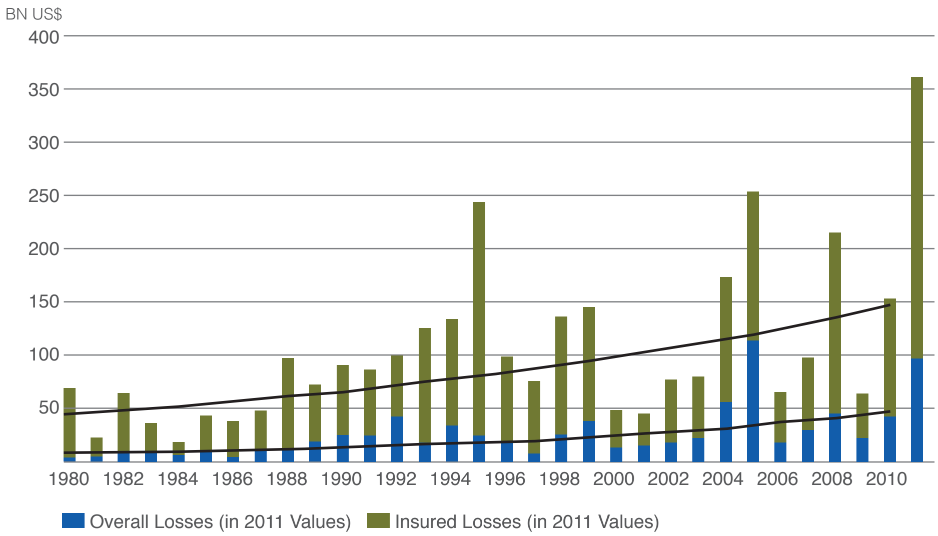
security was necessary for the country and that both a nation-wide recovery plan was needed as well as city-level recovery plans. This has also emphasized the need for an innovative and resilient energy system with a diversified and decentralised energy supply and management system, including the development of more flexible, locally-based energy supply and risk prevention facilities to quickly respond to risks.

Locally-based development for enhancing resilience

More than a decade has passed since the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1997, which commits its Parties to reduce their GHG emissions, thereby setting mitigation targets and related climate change policy at the national level. This has also prompted individual cities to do the same, oftentimes more successfully. For example, many local programmes and initiatives have been established in various countries[5], e.g., the Future City initiatives in Japan, Tianjin Eco-City in China, Thailand's Low Carbon City pilot project and the Low Carbon Society project in Iskandar Malaysia. In Japan's case, these city-based developments were launched as part of the National Strategic Projects in its 'New Growth Strategy'[6] published in June 2010.

In consideration of natural disasters, which are expected to become more frequent and severe as a result of climate change, governments must be proactive and take a preventative approach to constructing resilient infrastructure and management systems within the city

Figure 1 | Overall losses and insured losses worldwide between1980–2010 (US$ bn)



Source: Munich RE

Table 1 | Significant natural catastrophes worldwide in 2011: 5 costliest natural catastrophes ordered by overall losses

Affected Area	Event	Fatalities	Overall Losses (US$ M, Original Values)	Insured Losses (US$ M, Original Values)
Japan: Miyagi, Sendai; Fukushima, Mito; Ibaraki; Tochigi; Iwate; Yamagata, Chiba; Tokyo	Earthquake, Tsunami	15,840	210,00	35,000 - 40,000
Thailand: Phichit, Nakhon Sawan, Phar Nakhon Si Ayuttaya, Pathumthani, Nonthaburi, Bangkok	Floods	813	40,000	10,000
New Zeland: Christchurch, Lyttelton	Earthquake	185	16,000	13,000
USA: AL, AR, GA, IL, LA, MO, MS, OK, PA, TN, TX, VA	Severe Storms, Tornadoes	350	15,000	7,300
USA: AR, GA, IL, IA, IN, KS, KY, MD, MI, MN, MO, NC, NE, NY, OH, OK, PA, TN, TX, VA, VT, WI	Severe Storms, Tornadoes	178	14,000	6,900

Source: Adapted from © 2012 Münchener Rückversicherungs-Gesellschaft, Geo Risks Research, NatCatSERVICE

5 For more information see: http://futurecity.rro.go.jp/en/; http://www.tianjinecocity.gov.sg/; http://modelcities.hls-esc.org/Documents/Country-City%20Fact%20Sheet%20-%20MuangKlang.pdf; http://www.iskandarmalaysia.com.my/news/121127/iskandar-malaysia-to-be-a-low-carbon-%E2%80%98smart%E2%80%99-city

6 The New Growth Strategy policies (blueprint for revitalising Japan) were set up as a result of a Cabinet decision in 2010. One of the components is "Revitalizing rural cities and towns by utilizing regional resources; revitalizing big cities to serve as engines of growth. The targets to achieve by 2020 are to utilize regional resources to the greatest possible extent and increase regional power, and to make strategic, priority investments in airports, ports, roads, and other infrastructure in major urban areas" (Cabinet Decision, 2010).

> In order to avoid risks and damages, and to strengthen resilience to natural disasters, national *and* local governments need to be prepared.

or community in cooperation with private and local non-profit organisations. Assessment of the damages of disaster risks and the costs associated with natural disasters ex-ante is also important. Therefore, for fully effective risk management and implementation, locally-based facilities in line with an international risk management facility are needed.

After the recent sequence of natural disasters in Asia including the flooding in Thailand, earthquake in Indonesia, and earthquake and tsunami in Japan and their severe impacts on society, city-based risk management has become a major focus, particularly in Japan, and has been added in the components of local development strategies for enhancing resilience at this level. In Japan, an "autonomous decentralized regional development model project utilizing regional renewable energy"[7] was initiated in 2011(MOEJ, 2012 and 2013b). The private sector has been a key actor in the implementation and has also included other players such as research institutions and local governments.

Community-based management systems and investment

In order for a decentralised locally-based energy system to exist, funding is required for the installation and operation of new facilities, such as solar power generation stations. In Japan, increasing attention has been paid to the establishment of such financial mechanisms as the result of raised public awareness on sustainable energy and security. Available funds have been identified through government subsidies, but cannot be fully relied upon, making it important to seek out other sources. Various local funds have been established through investments from the private sector and also from voluntary citizen donations. Financial instruments have included the issuance of certificates, promissory notes, and small issue bonds through financial institutions like micro-credit funds[8], however, these instruments and methods vary and are dependent on the specific structures of funding within cities.

A challenge for local low-carbon energy investment availability and feasibility is the high degree of uncertainty and risks inherent in renewable energy technologies. Uncertainty is high due to the lack of experience and history in the case of green energy and community-based projects, and the lack of understanding on the associated social and environmental impacts as well as potential economic benefits. Therefore, local government and investors who provide subsidies or invest in these efforts must utilize proper analytical tools to estimate the cost-effectiveness of the local energy project including any economic, social and environmental impacts of its implementation prior to any decision-making.

Risk prevention and transfer

In addition to the establishment of locally-based energy systems, risk prevention or risk transfer systems mitigating the financial impacts of natural disasters must also be established at the local level. Agendas for the formulation of systems to reduce disaster risk and establishment of funding mechanisms such as risk financing have been attracting attention. Risk financing can be used as a measure to quickly secure funds before and after disasters, and also investigates countermeasures against natural disasters, including methods such as insurance and climate change adaptation measures. Economic loss attributed to extreme weather events around the world (IPCC, 2007 and 2012) increases the demand for the development of risk management and risk transfer schemes. Many countries, including both developed and also developing countries, have established such insurance schemes that improve adaptation capacity to disaster events.

One strategy to support the economic recovery immediately after a disaster includes a weather insurance index (ADB, 2007 and 2009). This allows for the benefit of quick payment to aid in

7 The project was implemented with additional funding of 1.0 billion yen in 2012. The budget was increased to 1.6 billion yen in 2013 under the programme of sustainable regional development (about 33 billion yen is planned to be distributed in 2013) according to the Ministry of the Environment budget request in 2013 (MOEJ, 2013a).

8 A micro-credit fund is an investment fund designed to finance microfinance institutions (MFIs), which provide financial services such as small loans to small enterprises. MFIs deliver microcredit through local banking, solidarity groups and individual loans. In the case of Japan, for instance, after the Fukushima accident, the online retail investment fund management company (Music Securities Inc, Tokyo, Japan) set up new micro-credit funds to raise capital for small enterprises in the Tohoku region, which has been hugely affected by the accident.

recovery post natural disaster due to the parameters of the index (e.g., the wind speed of a hurricane or the degree of ground acceleration caused by an earthquake) rather than the actual damages, which typically determine the conditions of payment. Use of these parameters aids in the liquidity of funding and helps insurees with more immediate recovery, as payments are paid as quickly as possible after the occurrence of disaster.

Development challenges

When introducing such a risk transfer mechanism, challenges are prone to exist in the development, the dissemination and the design of the risk transfer scheme. Uncertainty is high when disasters occur in places that in particular, lack appropriate infrastructure for pre-disaster management, data related to weather, or unreliable data with respect to quality. Other challenges include residual risk (i.e., the exposure to loss remaining after other known risks have been countered, factored in, or eliminated), the uncertainty of unexpected events due to the inability to quantify events of rare occurrence, the inaccuracy/unavailability of climate data, or poorly designed risk mitigation mechanisms and management systems (Suarez & Linnerooth-Bayer, 2011; Cummins & Mahul, 2009). These are all of particular concern within developing countries where high residual risk results in the generation of high insurance premium costs that small enterprises and citizens in developing countries cannot afford. Therefore, for minimizing the residual and baseline risk, governmental support to cover expected losses and risk premiums as well as to formulate reliable risk management mechanisms from accurate data including compiled historical data and capacity development is necessary.

Moreover, the challenges to the development of disaster risk insurance are profound in cities of developing countries that are disproportionately impacted by natural disasters such as typhoons, floods and drought, usually exacerbated by high population density and inadequate infrastructure. These challenges usually stem from the weaknesses which exist in observation systems including quality of data, availability of data, weather observation stations, the automation of the weather observation system to record and compile the data at the local/regional level (not only at the national level), and aging facilities and equipment. Therefore, for the improvement of risk prevention mitigation, first, the improvement of quality data and facilities to more accurately forecast and estimate risks is needed. The expansion, modernization and strengthening of a meteorological observation network is also necessary. Improvements in data processing are essential for the development of basic meteorological data for building a risk financing system, regardless of the field and approach of risk insurance or risk transfer mechanisms.

The aftermath of a tornado in Saint Louis, Missouri, USA

Conclusion

A policy package to prevent natural disaster risks at the local level including low carbon infrastructure, risk assessment for investment and risk transfer systems are needed. Future disaster preparedness requires the establishment of risk financing systems — it is necessary to have not only locally-based infrastructure systems such as community-based energy management and supply systems, and financing mechanisms, but also risk transfer mechanisms including risk insurance for natural disasters. In addition to the establishment of these systems at the local level, a basic infrastructure of data for risk assessment and estimates is required, and also a strengthening of regional or informational cooperation between cities or countries across both the developed and developing world. Finally, it is imperative, as in the case of Japan, to develop and build a collaborative environment for public institutions and private companies for the success of these locally-based initiatives.

References

Agency for Natural Resources and Energy (ANRE). (2012). *Energy statistic data* (in Japanese). Retrieved the raw data from: http://www.enecho.meti.go.jp/info/statistics/denryoku/index.htm

Asian Development Bank (ADB). (2007). *REGIONAL: Development of catastrophe risk insurance mechanisms* (Technical assistance consultant's report, Project number 39109). Jonathan Hill, Fount, LLC and Russell Blong, Blong & Associates.

Asian Development Bank (ADB). (2009). *Natural catastrophe risk insurance mechanisms for Asia and the Pacific: Main report.* Mandaluyong City, Philippines: Asian Development Bank.

Cabinet Decision. (2010). *On the new growth strategy, blueprint for revitalizing Japan* (Provisional translation, June 18, 2010). Retrieved from: http://www.meti.go.jp/english/policy/economy/growth/report20100618.pdf

Chongvilaiva, A. (2012). *Thailand's 2011 flooding: Its impact on direct exports, and disruption of global supply chains* (ARTNeT Working Paper No. 113, May). Bangkok, Thailand: ESCAP.

Cummins, J. D., & Mahul, O. (2009). *Catastrophe risk financing in developing countries: Principles for public intervention.* Washington D.C.: The International Bank for Reconstruction and Development/The World Bank.

Geneva Association. (2009). *The insurance industry and climate change: Contribution to the global debate* (The Geneva Reports, Risk and Insurance Research, No. 2, July 2009). Geneva, Switzerland: The Geneva Association.

Intergovernmental Panel on Climate Change (IPCC). (2007). *Climate change 2007: Impacts, adaptation and vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (Eds.). Cambridge, UK: Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation.* A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. C.B. Field, V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (Eds.). Cambridge, UK, and New York, NY, USA: Cambridge University Press.

Ministry of Environment Japan. (MOEJ). 2012. *Government activity review sheet in 2012* (in Japanese). Retrieved from: http://www.env.go.jp/guide/budget/spv_eff/review_h24/sheets_h24f/sheets/24-028.pdf

Ministry of Environment Japan. (MOEJ). (2013a). *Overview of the Ministry of the Environment budget request in 2013* (in Japanese). Retrieved from: http://www.env.go.jp/guide/budget/h25/h25juten-1.pdf

Ministry of Environment Japan. (MOEJ). (2013b). *Fiscal budget request for autonomous decentralized regional development model project utilizing regional renewable energy in 2013* (in Japanese). Retrieved from: http://www.env.go.jp/guide/budget/h25/h25-gaiyo-kai/005.pdf

Munich Climate Insurance Initiative. (MCII). (2008). *Insurance instruments for adapting to climate risks* (A proposal for the Bali Action Plan1, Version 2.0, September 30, 2008). Retrieved from: http://unfccc.int/resource/docs/2008/smsn/ngo/033.pdf

Suarez, P., & Linnerooth-Bayer, J. (2011). *Insurance-related instruments for disaster risk reduction* (Final Draft — October 4, 2010). Submitted to the International Strategy for Disaster Reduction (UNISDR), The 2011 Global Assessment Report on Disaster Risk Reduction. Retrieved from: http://www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/Suarez_&_Linnerooth-Bayer_2011.pdf

World Bank. (2013). *Improving the assessment of disaster risks to strengthen financial resilience* (A special joint G20 publication by the Government of Mexico and the World Bank). Washington D.C.: International Bank for Reconstruction and Development/International Development Association or The World Bank.

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