Institution: University of Manchester

Unit of Assessment: UoA05

Title of case study: Climate-proofing cities using urban greenspace

1. Summary of the impact

Urban greenspace cools cities and reduces rainfall runoff but these effects have been difficult to quantify. Ennos's research is the first to give realistic figures for the contribution of greenspace and assess its potential to climate-proof cities. Key research findings have furthered the concept of green infrastructure, influenced local and national planning policy [text removed for publication]. Novel mapping tools developed by Ennos have had international impact, including use in the city master plan for Addis Ababa, Ethiopia. Community forests have altered their planting practises as a result of Ennos's research findings.

2. Underpinning research

The impact is based on research that took place at the University of Manchester from 1999 to 2013. The key researchers are:

Dr Roland Ennos (Reader, 1999-2013)
Professor John Handley (1999-2010)
Dr Sarah Lindley (Lecturer, 2003 to date)
Dr Stefan Pauleit (Lecturer, 2003-2006)
Ms Victoria Whitford (MSc Student, 1999-2000)
PhD students: Dr Susannah Gill (2003-2007), Dr David Armson (2008-2012), Mr Asrafur Rahman (2009 to date)

The overall aim of the research was to quantify the physical benefits of urban greenspace. The first stage (1999-2007) was to customise theoretical models of the surface temperature and hydrology of urban areas [1], and the data were then used to investigate the effect of environmental change in Merseyside [2]. Handley and Ennos led the project and supervised or co-supervised the postgraduate students listed above. Collaborators were Oxford Brookes University who investigated the effects of cooling on human comfort and Southampton University who specifically studied flooding.

Ennos selected and customised models for use in the UK, including:

- *Surface temperature model* to predict mean maximum and minimum surface temperatures from meteorological and land cover data
- *Hydrology model* that estimates runoff coefficients based on the built environment, soil type and vegetation
- *Diversity model* based on the total area of greenspace and structural diversity

Geographic Information Systems (GIS) and aerial photograph interpretation was used to map greenspace across Greater Manchester. The information was input into the models to map surface temperature and runoff across the city, both for current climate and for future climates [3] as predicted by the UK Climate Impacts Program. The research also investigated the likely effect of changes to greenspace [3].

Key datasets were developed including Urban Morphology Typology (UMT) units that characterise the urban environment [4]. The UMT units combine biophysical characteristics with other features that are relevant to planning to provide a robust geographical outline of neighborhoods that can be used for analysis, assessment and planning.

The key advances were:

- Mapping the extent of greenspace over a complete city [4]. This is the first time that a whole city has been mapped and provides a unique opportunity to quantify the environmental contribution of greenspace in reducing the urban heat islands and preventing surface flooding [3].
- Specific recommendations, based on modelling data were;
  - A 10% increase in Manchester city centre greenspace would reduce surface temperatures by 4°C, climate proofing the city until 2080. It would also reduce rainfall runoff by 7%,

helping to prevent urban flooding [3].
  - Adding green roofs to buildings can have a dramatic effect in reducing maximum surface temperatures [3].
  - Greenspace is most effective at reducing surface runoff on sandy soils.

Research from 2008 to 2013 was experimental and aimed at investigating the actual local environmental effects of trees and other greenspace.

The key findings were:
- In hot weather, trees can reduce the Physiological Effective temperature (and so cool people) by 7°C [5] and cool surfaces by up to 20°C [6].
- To maximise growth rate and cooling properties, trees should be planted in urban soils rather than in grass verges [5].
- Trees reduce surface runoff by 60% in rain storms.

3. References to the research

The research has been published in leading journals in the field, with most papers in the leading planning journal *Landscape and Urban Planning*. Paper 3 won the DCLG Planning Research Network Prize Paper Competition in 2007.

1. **Whitford, V.L., Ennos, A.R, Handley, J.W.** (2001) "City form and natural process" – Indicators for the ecological performance of urban areas and their application to Merseyside, UK. *Landscape and Urban Planning.* 57. p. 91-103. DOI: 10.1016/S0169-2046(01)00192-X
2. **Pauleit, S**., Golding, Y.C., **Ennos, A.R.** (2005) Modeling the environmental impacts of urban land use and land cover change – a study in Merseyside, UK. *Landscape and Urban Planning.* 71. p. 295-310. DOI: 10.1016/j.landurbplan.2004.03.009
3. **Gill, S., Handley, J.F., Ennos, A.R., Pauleit, S.** (2007). Adapting cities for climate change: the role of the green infrastructure. *Built Environment.* 33. p. 97-115. DOI: 10.2148/benv.33.1.115
4. **Gill, S., Handley, J.F., Ennos, A.R., Lindley, S.,** Theuray, N., **Pauleit, S.** (2008). Characterising the urban environment of UK cities and towns: a template for landscape planning. *Landscape and Urban Planning.* 87. p. 210-222. DOI: 10.1016/j.landurbplan.2008.06.008
5. **Rahman, M.A.,** Smith, J.G., Stringer, P., **Ennos, A.R.** (2011). Effect of rooting conditions on the growth and cooling ability of *Pyrus calleryana*. *Urban Forestry and Urban Greening.* 10. p. 185-192. DOI: 10.1016/j.ufug.2011.05.003
6. Armson, D., Stringer, P., **Ennos, A.R.** (2012). The effect of tree shade and grass on surface and globe temperatures in an urban area. *Urban Forestry & Urban Greening.* 11. p. *245-255.* DOI: 10.1016/j.ufug.2012.05.002

4. Details of the impact

Context

Lack of urban greenspace can lead to problems such as urban heat islands and flooding. Before this research, most climate prediction models answered very specific questions and required high level input. This research enabled the development of accessible and easy-to-use tools that planners can use to design urban greenspace intelligently and has informed policies on a local, national and international scale.
The work is at the boundary between scientific research, policy making and adaptation practice, bringing together the organisations and people responsible for addressing the challenges that climate change will bring.

Pathways to impact

- Customised models have been made publically and freely available online as STAR tools: Surface Temperature And Runoff tools for assessing the potential of green infrastructure in adapting urban areas to climate change. The site had 610 unique visitors from 351 different organisations in the period 1st Feb - 22nd Oct 2012 [text removed for publication] with other

international visitors from Singapore, Germany, Japan and Brazil.

- Meeting with stakeholders, seminars and talks across the UK and Europe by the research team led to the widespread dissemination of the research.

Reach and significance of the impact

Influencing international planning:

- The UMT approach has been adopted in five African cities including Saint Louis (Senegal), Addis Ababa (Ethiopia), Dar Es Salaam (Tanzania), Douala (Cameroon) and Ouagadougou (Burkina Faso). In Addis Ababa in particular, the UMT dataset has already helped the effective engagement of local stakeholders and is to form the foundation of the city's new Master Plan (May 2013). [Text removed for publication] [A].
- In terms of the importance of urban vegetation for aesthetics and biodiversity, Whitford et al [1] was cited in the proceedings of the Ecocity World Summit 2008 [B]. This is a cross-disciplinary World Summit on Sustainable Cities, supported by the non-profit organisation, Ecocity Builders, who aim to reshape cities for the long-term health of human and natural systems. Ecocity Builders are a global network that works in partnership with the United Nations to develop and implement policies on a global scale.

Informing national policy:

- The Forest Research report to the Department for Environment, Food and Rural Affairs (DEFRA) and the Department for Communities and Local Government (DCLG), titled '*Benefits of green infrastructure'* [C] cites data from Whitford et al [1] and Gill et al [3]. This report examined how the policy objectives of DEFRA and DCLG could be supported based on evaluation of scientific literature. Whitford et al [1] is cited under 'hydrological benefits' of greenspace and Gill et al [3] is cited under 'heat amelioration' and 'sustainable urban drainage' as 'environmental benefits' of green infrastructure.
- Following on from the Forest Research report to DEFRA and the DCLG [C], the DCLG produced a National Planning Policy Framework [D].
- The 2012 guidance document produced by CIRIA (Construction Industry Research and Information Association), '*The benefits of large species trees in urban landscapes'* [E], was influenced by the findings of Gill et al [3] in terms of 'costing, design and management'. Users of the guidance document include developers, local authorities, planners, highways authorities, landscape architects and arboricultural managers.

Informing the planting practices of community forests:

- In collaboration with partners, Community Forests North West, research regarding optimal planting conditions for street trees is being widely disseminated to the arboricultural, planning and architecture community. [Text removed for publication] [F].

Influencing policy and securing funding for tree planting in London:

- [Text removed for publication] [G] [H].

Informing the Manchester Climate Change Action Plan:

- Ennos's research has influenced the strategy of local governments in the North West. The 2009 Manchester Climate Change Action Plan [I], published by Manchester City Council, includes models to show the maximum surface temperature in Greater Manchester from 1970-2080, with reference to Gill's PhD thesis.
- Research findings were incorporated into the Greater Manchester Climate Strategy for 2011-2020 [J] under the action 'Green and Blue Infrastructure'.

5. Sources to corroborate the impact

A. Letter from Greenspace Planning Expert, Addis Ababa City Planning Project Office, *corroborating use of data in the Addis Ababa city master plan.*

B. Ecocity World Summit 2008 Proceedings. Ecological Engineering, Green Roofs and the Greening of Vertical Walls of Buildings in Urban Areas.

C. Forest Research (2010). *Benefits of green infrastructure*. Report to DEFRA and DCLG: http://www.forestry.gov.uk/pdf/urgp_benefits_of_green_infrastructure_main_report.pdf/$FILE/urgp_benefits_of_green_infrastructure_main_report.pdf

D. Department for Communities and Local Government (DCLG) National Planning Policy Framework, March 2012: http://www.communities.gov.uk/publications/planningandbuilding/nppf

E. CIRIA (2012). The benefits of large species trees in urban landscapes: a costing, design and management guide. http://www.ciria.org/service/Web_Site/AM/ContentManagerNet/ContentDisplay.aspx?Section=Web_Site&ContentID=22853

F. Letter from Forest Director of Red Rose Forest, *corroborating uses of research data.*

G. Statement from Transport for London Press Office, *verifying the tree planting strategy for London.*

H. Email from Route Manager for Arboriculture and Landscape at Transport for London, *corroborating that data led to increased tree planting.*

I. Manchester. A Certain Future. Our co_2llective action on climate change. Manchester Climate Change Action Plan. http://cdn.faelix.net/creativeconcern/manchesterclimate/ManchesterClimateChangeActionPlan.pdf

J. Association of Greater Manchester Authorities (AGMA), Greater Manchester Climate Strategy for 2011-2020: http://meetings.gmwda.gov.uk/mgConvert2PDF.aspx?ID=8975