Spatial modelling and web-GIS tools for climate change adaptation planning in urban areas

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Contents

• Introduction
• Modelling impacts of climate and land use change on temperatures
• Vulnerability of communities, climate hazards and green infrastructure
• Web-GIS tools for climate change adaptation planning
Climate change impacts in the built environment

• The built environment
  – High building mass increases thermal capacity
  – Surface sealing increases rainfall run-off

• Climate change:
  – Intensifies the urban heat island effect
  – Increases risk of flooding
Green Infrastructure (GI)

Life support system – the network of natural environmental components and green and blue spaces that lies within and between our cities, towns and villages, and provide multiple social, economic and environmental benefits.
Benefits of GI

- Multiple benefits of GI – 11 economic benefits identified
- Climate adaptation benefits include:
  - Heat amelioration
  - Reducing flood risk
  - Improving water quality
  - Sustainable urban drainage
  - Improving air quality

Figure 1: The economic benefits of green infrastructure

SOURCE: ECOTECH 2009
Greening the corridor – Modelling land use change and temperature

Research objectives:

– To understand the impacts of climate change and land use change on surface temperatures in the Oxford Road Corridor neighbourhood

– To transfer knowledge and investigate the perceptions that organisations have of these changes in order to understand how a green scenario can be realised
Modelling climate and land use change in The Corridor

Methodology:

- Surface cover analysis of current situation using aerial photography
- Alteration of surface cover to create two potential future greening/development scenarios
- Analysis of baseline climate & projections for Manchester
- Modelling of surface temperatures under different development and climate scenarios
  - Using an energy exchange model to simulate surface temperatures on the 2 hottest days in summer (Tso 1990; 1991; Whitford et al., 2001; Gill, 2006)
Surface cover analysis

Proportional cover

- Greater Manchester average
- Town centre
- Offices
- The corridor

ASCCUE Urban Morphology Type

EcoCities case study

Bare soil
Evapotranspiring
Built

15% green space
56% impervious surfaces
27% buildings

Where could land use change?
- 161 flat roofs that could be greened (9%)
- Large sealed surfaces and carparks (8%)
- Green infrastructure other than parks and water (11%)
Future development scenarios

- **Business as usual** – current situation
  - 15% green space

- **High development**
  - 4% green space
  - Flat roofs greened by 100%
  - Large sealed surfaces and car parks greened by 50%
  - Trees planted along roads (greened by 30%)

- **Deep green**
  - 34% green space
  - All green space (excluding parks and water) is developed
  - Flat roofs greened by 100%
  - Large sealed surfaces and car parks greened by 50%
  - Trees planted along roads (greened by 30%)
Results: Impact of changing surface cover on surface temperature

<table>
<thead>
<tr>
<th>Development Scenarios</th>
<th>1961-1990</th>
<th>Business as usual</th>
<th>Deep green</th>
<th>High development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current situation</td>
<td>~21%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>green space</td>
<td>maintain</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>surface temperatures at baseline</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **High development**: 4% green space = +5°C
- **Business as usual**: 15% green space
- **Deep green**: 34% green space = -6°C

- ~21% green space will maintain surface temperatures at baseline
Common adaptation strategy

The partnership working together
- Strength of the structure
- Presence of large organisations

Focus on environmental agenda
- A number of programmes, trials and models focused around the corridor
- Recognition of mitigation/adaptation
- Individual & collective signatories to MCC CCAP

The partnership does not include all parties

Institutional barriers
- Governance structures
- Investment – timing
- Short time horizons

Climate change agenda
- Overall focus on mitigation
- Understanding the consequences
- Confusion mitigation / adaptation actions

Retrofit cost

Future changes (technology, policy, culture)
- Sustainability becoming the priority
- ITC development - less city working
- Increasing public awareness of CC

Adaptation = economic competitiveness:
- Attractiveness of the area
- Reputation

Bright future for the partnership
- City leadership
- Peer pressure
- Ongoing common schemes = stronger future collaboration

Cost

Ongoing political changes
- Existence / functioning of organisations

High numbers of climate change sceptics

VAT penalty on services

Short-termism
- Investment
- Political power
## Realising the Green scenario

<table>
<thead>
<tr>
<th>SWOT</th>
<th>GI awareness</th>
</tr>
</thead>
</table>
| **GI awareness** | • Multiple benefits  
• GI and development not mutually exclusive |
| **GI aligned with The Corridor priorities** | • Quality of place  
• Attractiveness = competitiveness |
| **A number of ongoing greening initiatives** | |
| **Limited number of land owners** | |

<table>
<thead>
<tr>
<th>SWOT</th>
<th>Financial issues:</th>
</tr>
</thead>
</table>
| **Financial issues:** | • Upfront investment & long payback time  
• Uncertainty over benefits |
| **Limited influence of spatial planning** | • Densely developed area  
• Large proportion owned by private sector |
| **Space** | • Limited green space provision  
• Space shortage |
| **Practical issues** | • Technology (green roofs)  
• Maintenance (brown grass; impact on utilities) |

<table>
<thead>
<tr>
<th>SWOT</th>
<th>Future lifestyle and technological changes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Future lifestyle and technological changes</strong></td>
<td>• Fewer roads &amp; car parks = more green space</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWOT</th>
<th>National funding for green infrastructure</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>SWOT</th>
<th>Working together</th>
</tr>
</thead>
</table>
| **Working together** | • City planners on board  
• Learning from others & exchanging experience |

<table>
<thead>
<tr>
<th>SWOT</th>
<th>Incorporating GI into daily business</th>
</tr>
</thead>
</table>
| **Incorporating GI into daily business** | • Greening alongside infrastructure works  
• Green procurement |

<table>
<thead>
<tr>
<th>SWOT</th>
<th>Weaknesses of the planning system</th>
</tr>
</thead>
</table>
| **Weaknesses of the planning system** | • Driven by economic goals  
• Environmental agenda separate  
• Limited regulatory powers of the city |

<table>
<thead>
<tr>
<th>SWOT</th>
<th>Spending cuts in public sector</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>SWOT</th>
<th>Public perceptions</th>
</tr>
</thead>
</table>
| **Public perceptions** | • Lack of respect for open spaces  
• Climate sceptics |

<table>
<thead>
<tr>
<th>SWOT</th>
<th>Maintaining functional green space under changing climate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maintaining functional green space under changing climate</strong></td>
<td>(Cavan &amp; Kazmierczak, 2011)</td>
</tr>
</tbody>
</table>
Surface Temperature And Runoff (STAR) tool

http://www.ppgis.manchester.ac.uk/grabs/

STAR tools

Surface temperature and runoff tools for assessing the potential of green infrastructure in adapting urban areas to climate change.

The STAR tools allow users to assess the potential of green infrastructure in adapting their areas to climate change. They include a surface temperature tool and a surface runoff tool.

The STAR tools can be used at a neighbourhood scale (in the North West of England and beyond) to test the impact of different land cover scenarios of greening and development on surface temperatures and runoff, under different temperature and precipitation scenarios.

Outputs of the STAR tools can be used to inform policy, strategy, and development. They are of use to a range of professionals and organisations with an interest in understanding more about the influence of urban greening on their local climate. This includes planners, developers, masterplanners, local authorities, urban forestry initiatives, NGOs and academics.

Please use the below links to find guidance on

- Using the tools
- Why they are needed
- The scale they can be used at
- Input requirements (in North West England and beyond)
- What the output looks like
- Applications
- The models underpinning the tools
High temperature hazard – conurbation scale

For a day occurring on average twice per summer

(Gill, 2006)
Vulnerability of people & communities to climate change

• People have different capacity to deal with hazards
• So therefore not everyone is affected to the same extent
• Coping capacity is dependant on:
  ▪ Access to information – social networks; language
  ▪ Ability to prepare for flooding / heat – resources e.g. insurance
  ▪ Capacity to act in the case of emergency – knowledge; ability
  ▪ Ability to recover after flooding – resources; physical & mental strength

(Kazmierczak & Cavan, 2011)
Spatial distribution of vulnerability

- Four principal groups
- High scores of poverty & diversity components concentrated around urban centres
- High scores of children component located in sub- and peri-urban areas
- High scores of old age component more scattered distribution across suburban areas

(Kazmierczak & Cavan, 2011)
Vulnerable communities & climate-related hazards

- Correlations between vulnerability and surface water flooding

Aspects of vulnerability of communities and the intensity of the urban heat island

<table>
<thead>
<tr>
<th>Principal components</th>
<th>All areas susceptible to flooding</th>
<th>High susceptibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC1: Poverty</td>
<td>0.056*</td>
<td>Ns</td>
</tr>
<tr>
<td>PC2: Diversity</td>
<td>0.139***</td>
<td>-0.234***</td>
</tr>
<tr>
<td>PC3: Children</td>
<td>-0.099***</td>
<td>-0.059*</td>
</tr>
<tr>
<td>PC4: Old age</td>
<td>-0.111***</td>
<td>Ns</td>
</tr>
</tbody>
</table>

(Kazmierczak & Cavan, 2011; Kazmierczak, 2012)
Flood risk, housing and tenure

Factors enhancing vulnerability e.g. housing and tenure

<table>
<thead>
<tr>
<th>Percentage of LSOA in flood risk area</th>
<th>Tenure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Owner-occupied</td>
</tr>
<tr>
<td>Surface flood &gt;0.1m</td>
<td>0.140**</td>
</tr>
<tr>
<td>Surface flood &gt;1.0m</td>
<td>0.071**</td>
</tr>
</tbody>
</table>

- Correlations between tenure and surface water flooding

(Kazmierczak & Cavan, 2011)
Vulnerable communities, green space and housing

<table>
<thead>
<tr>
<th></th>
<th>PC1: poverty</th>
<th>PC2: diversity</th>
<th>PC3: children</th>
<th>PC4: old age</th>
</tr>
</thead>
<tbody>
<tr>
<td>% total green space</td>
<td>-0.269***</td>
<td>-0.559***</td>
<td>0.056*</td>
<td>Ns</td>
</tr>
<tr>
<td>% gardens</td>
<td>-0.269***</td>
<td>0.199***</td>
<td>0.231***</td>
<td>0.113***</td>
</tr>
<tr>
<td>% houses with lowest floor at/below ground level</td>
<td>-0.347***</td>
<td>-0.553***</td>
<td>0.457***</td>
<td>-0.110***</td>
</tr>
<tr>
<td>% semi- and detached houses</td>
<td>-0.617***</td>
<td>-0.449***</td>
<td>0.337***</td>
<td>0.055*</td>
</tr>
<tr>
<td>% terraced houses</td>
<td>0.535***</td>
<td>0.209***</td>
<td>-0.080**</td>
<td>-0.130***</td>
</tr>
<tr>
<td>% houses in poor condition</td>
<td>0.382***</td>
<td>0.543***</td>
<td>-0.372***</td>
<td>Ns</td>
</tr>
</tbody>
</table>

Ns – not significant.

* Significant at 0.10 level.
** Significant at 0.05 level.
*** Significant at 0.01 level.

(Kazmierczak & Cavan, 2011)
Climate adaptation planning: developing an urban climatic map

- Incorporating climate in urban planning & design is not a new idea
- An Urban climatic map (UCMap) can be a valuable tool to aid urban planners
- Implemented in over 15 countries worldwide (Ren et al. 2011)
- Cities in Europe (particularly in Germany) & Asia (e.g. Hong Kong) are leading the development of UCMaps, often as a response to critical events
Risk map for flood events

Hazard

Exposure

Vulnerability

Risk

(Smith, Cavan & Lindley, 2012)
Urban climate recommendation map

Built-up, high sensitivity
Limited green space, high risk areas; restricted development & adaptation encouraged

Neutral
Redevelopment not possible (transport, etc)

Open, high sensitivity
Unused or PDL in high risk areas restricted from development

Climatically active
Green space in low risk areas should have restricted development

(Climate Planning Zones)

Neutral
Climatically Active, Low Sensitivity Area
Climatically Active, High Sensitivity Area
Open, High Sensitivity Area
Built-up, High Sensitivity Area
Built-up, Very High Sensitivity Area
Air Quality Management Areas
Major Roads

(Smith, Cavan & Lindley, 2012)
EcoCities: The Bruntwood Initiative for Sustainable Cities

www.adaptingmanchester.ac.uk
EcoCities Spatial Portal
www.ppgis.manchester.ac.uk/ecocities

The EcoCities Spatial Portal

assessing the geography of Greater Manchester's vulnerability to climate change

The spatial portal is an interactive platform that displays spatial data and provides information to improve understanding of issues of climate change vulnerability in Greater Manchester, helping to build the evidence base available to decision makers and other stakeholders when developing climate change adaptation plans and strategies.

The spatial portal is for all stakeholders, including community members, to visualise vulnerability, exposure and climate hazards within a particular location, thus raising awareness, aiding decision-making and facilitating community and stakeholder participation in formulating appropriate adaptation responses.

Launch the Tool

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Mapping hazard, vulnerability and exposure

www.ppgis.manchester.ac.uk/ecocities
Conclusion

• Cities which understand and manage their climate are ahead in the challenge to adapt to climate change (Stuttgart, 2010)

• GI has multiple benefits and offers potential to help adapt cities for a changing climate

• Adaptation requires spatially targeted actions that consider differences in the physical environment, community development, social infrastructure, green infrastructure...
Thank you

References

- Cavan & Kazmierczak (2011). Urban greening to adapt urban areas to climate change. EcoCities, University of Manchester.

EcoCities website: [www.adaptingmanchester.ac.uk](http://www.adaptingmanchester.ac.uk)
STAR tools: [www.ppgis.manchester.ac.uk/grabs](http://www.ppgis.manchester.ac.uk/grabs)