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Multifunctional green infrastructure and climate change adaptation: brownfield greening as an adaptation strategy for vulnerable communities?

1. Introduction

The years 2011-2015 have been the warmest five-year period on record and were charcterised by occurrence of heatwaves, droughts and cyclones (WMO, 2015). The rapidly progressing climate change is seen as the biggest threat to public health this century (Costello et al., 2009). In temperate regions, severe but infrequent temperature fluctuations increase weather-related mortality (McGeehin & Mirabelli, 2001). The European heatwave in August 2003, with peak temperatures ranging from 38.5°C in England to 47°C in Portugal (Poumadere, Mays, Le Mer & Blong, 2005), caused an estimated 70,000 additional deaths across Europe (Robine et al., 2008); over 2,000 people died in England alone (ONS, 2005). Climate projections suggest that such heat extremes will occur more frequently (Coumou & Robinson, 2013), which is likely to have further implications for human health.

The effects of high temperatures on well-being are not evenly spread across societies. The unequal susceptibility to harm is captured by the concept of vulnerability. Whilst many contested notions of vulnerability exist, the factors increasing vulnerability to high temperatures may be divided into: personal, such as age and health, as the well-being of older people, young children and those in poor health is likely be affected the most; socio-economic, such as income, ability to speak the official language, social isolation, tenure, or even the perceived crime levels, affecting the decisions to open windows on hot nights; and environmental: the propensity of housing to overheating (e.g. people in top floor flats experience higher rates of heat-related morbidity and mortality than those living on lower floors) and the presence of vegetation (Lindley et al., 2011).

Research indicates that green spaces substantially mitigate the effects of high temperatures in cities, thereby reducing the health risks to vulnerable people (Demuzere et al., 2014). Grass surfaces exposed to sun may be 24°C cooler than concrete, and tree shade may lower air temperatures by 5-7°C (Armson, Stringer & Ennos, 2012). Urban parks are on average 1°C cooler than built-up areas, with larger parks having a more substantial cooling effect (Bowler, Buyung-Ali, Knight & Pullin, 2010); measurements around Kensington Gardens (London) showed temperature reductions of up to 4°C and cooling occuring up to distances of around 400m (Doick, Peace, & Hutchings, 2014). Modelling for Greater Manchester suggests that, under the changing climate, a 10% increase of green space in densely built-up areas would help to maintain the current temperatures at the end of the 21st century (Gill, Handley, Ennos & Pauleit, 2007). On the contrary, decreasing the green space in Manchester city centre from 15% to 4% would raise the average surface temperatures by 5.6-9.2°C (Carter et al., 2015). Therefore, one method of adapting cities to future high temperatures is increasing the presence of green spaces.

This brief paper focuses on a particular land use type that could hypothetically be greened to alleviate high temperatures' effects on the well-being of the most vulnerable in the society: brownfields, or previously developed land. The potential of converting brownfields in England into green spaces is explored, considering their geographical distribution, proposed use and ownership. A case study of the post-industrial conurbation of Greater Manchester is considered, where the spatial associations between location of brownfields, levels of social vulnerability and urban heat island extent are analysed. The findings are discussed in the context of current debates on brownfield redevelopment in the UK.

2. Brownfields and social vulnerability to high temperatures in England

According to the National Land Use Database (NLUD) in 2010 there were nearly 24,000 brownfield sites in England; almost 48,000 hectares in total (HCA, 2010) [1]. Brownfields are not evenly spread across the country, but tend to concentrate in cities and areas of previous industrial activity (Longo & Campbell, 2016; Figure 1). Figure 1 also presents the levels of social vulnerability to high temperatures per local authority. The vulnerability was assessed within the ClimateJust project, utilising the conceptual framework by Lindley et al. (2011), whereby the vulnerability index is a combination of personal, socio-economic and environmental factors. The assessment was carried out at the level of Middle-layer Super Output Areas (MSOAs; census units of around 5,000 – 7,000 population), using census 2011 data as the main information source[2].

 # Figure 1 approximately here #

At the local authority level, the percentage of MSOAs of above-average vulnerability was moderately correlated with the percentage of area covered by brownfields ($r=0.509$; $p<0.001$). At the finer scale, higher vulnerability of individual MSOAs ($N=6791$) is also associated with an increasing number and area of brownfield sites per MSOA (Figure 2). Therefore, it seems that brownfields coincide spatially with the most vulnerable communities and thus have the potential to provide cooling services, if greened.

 # Figure 2 approximately here #

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[1] This paper is based on the 2010 National Land Use Database (NLUD data when all local authorities were obliged to provide information on previosuly developed land. Data from the more recent 2012 data is incomplete, as only 50% of local authorities submitted data (Future spaces foundation, 2015).
[2] The technical information on the assessment of vulnerability and the complete dataset are available on www.climatejust.org.uk.

The potential for greening of brownfield sites is likely to be affected by their proposed use and ownership (HCA, 2010). In England, only 1% of brownfields (249 sites; 3.1% of the total brownfield area) are proposed to be re-used as open space (Figure 3). Further, nearly 59% of the brownfield sites are privately owned, whilst local authorities and other public bodies own, respectively, just over 10% and 5%. However, with escalating levels of vulnerability, the proportion of brownfield sites that are owned by local authorities and other public bodies also increases (Figure 4); in the MSOAs characterised by 'acute' social vulnerability to high temperatures, a quarter of brownfield sites are owned by either local authorities or public bodies. Therefore, in areas characterised by the highest social vulnerability, local authorities may have more control over the future development of the brownfield sites, and potentially dedicate some of them to soft-end uses.

 # Figure 3 approximately here #

 # Figure 4 approximately here #

3. The case of Greater Manchester

In large cities, such as Greater Manchester, high temperatures are intensified by the urban heat island (UHI) effect, whereby urban areas exhibit higher temperatures relative to their surroundings due to the thermal mass of buildings and hard surfaces and the emission of heat from anthropogenic activities. In the Manchester city centre, the air temperatures may be up to 5°C higher than on the peripheries of the conurbation (Smith, Webb, Levermore, Lindley & Beswick, 2011), which may exacerbate the impacts of extreme temperatures on the well-being of inner-city communities.

The locations of brownfields in Greater Manchester - 2,200 sites of 4,200 ha (Polyakova, 2011) - coincide spatially with higher levels of social vulnerability (Figure 5) and with the intensity of UHI (Figure 6). Therefore, in general, converting brownfield land in Greater Manchester to green spaces may provide cooling services where they are needed, considering both the social and physical characteristics of the locations.

 # Figure 5 approximately here #

 # Figure 6 approximately here #

However, similarly to the situation in England as a whole, only a small proportion of brownfield land in Greater Manchester is proposed as open space (31 sites, or 609 hectares in total). This reduces the chances of a large-scale greening programme. Moreover, the brownfields proposed as open spaces tend to be located outside the UHI (Figure 7); thus, if they are converted to green spaces, their cooling benefits may not be optimally located.

 # Figure 7 approximately here #

4. The potential for greening the brownfields in vulnerable neighbourhoods

The above rough and ready analysis suggests a substantial capacity of brownfields (considering their location, number and total area) to provide cooling services as green spaces, in neighbourhoods assessed as vulnerable to high temperatures. In particular, the Greater Manchester case study shows associations among the levels of social vulnerability to high temperatures, intensity of the UHI and the presence of brownfields.

Soft-end re-use of brownfields, alongside the direct role in adaptation to high temperatures through cooling, provides multiple benefits to urban communities, which may help to address some of the underlying factors of social vulnerability to climate change (Demuzere et al., 2014). People living in greener neighbourhoods tend to be healthier, including the potentially more vulnerable to high temperatures groups, such as older people (Takano, Nakamura & Watanabe, 2002) and those on lower incomes (Mitchell & Popham, 2008). Presence of green space also improves neighbourhood social ties (Kazmierczak, 2013; Kuo, Sullivan, Coley, & Brunson, 1998), which for isolated individuals may be lifelines in extreme temperatures (Klinenberg, 1999). In addition, the severity of other climate-related impacts such as surface water flooding may be mitigated by the presence of vegetation (Demuzere et al., 2014). Therefore, converting brownfields to green spaces in vulnerable neighbourhoods may be seen as a sustainable, long term adaptation strategy providing auxiliary ecosystem services to urban dwellers.

However, when the proposed future uses are considered, the scale of brownfield greening is likely to be miniscule. Whilst between 1988 and 1993 over 19% of brownfield sites in the UK were converted into green spaces, exceeding any other end use (de Sousa, 2003), more recently the emphasis on high-density development promotes turning brownfield land into hard-end uses (CPRE, 2014, Future Spaces Foundation, 2015; McEvoy, Lindley and Handley, 2006). Today the main competing redevelopment direction for brownfields in England is housing, as extra 222,000 new homes are needed annually over the period 2011-31 to address the housing shortage (DCLG, 2015). Through the targets set under the previous planning system, 81% of houses were built on previously developed land in 2008; in 2011 - 64% (DCLG, 2013). The National Planning Policy Framework (NPPF) encourages '...the effective use of land by reusing land that has been previously developed (brownfield land)' (DCLG, 2012: 26). Further, through the recently proposed Housing and Planning Bill, the government intends to give "automatic" permission to housing schemes on brownfields allocated for that use to increase the scale of housing construction (HM Treasury, 2015). In addition, the government's plans to partially address the housing crisis through provision of new settlements (new generation of ‘Garden Cities’), which could lessen the pressure on brownfields, have been met with severe criticism (CPRE, 2014; Future Spaces Foundation, 2015). Developing brownfield land is hailed as the most sustainable option, reducing urban sprawl and transport needs. However, the longer-term implications of densification of cities under the changing climate are missing from the debate, whilst research suggests that infill densification and brownfield development are likely to magnify the negative climate change impacts (Carter et al., 2015; Pauleit, Ennos & Golding, 2005). Thus, the extant emphasis on compact developments is in conflict with adaptation strategies based on urban greening (McEvoy et al., 2006). Further, other sustainability aspects of brownfield development are rarely discussed; for example, the impact of house-building on brownfields on reducing socio-economic deprivation varies (Longo & Campbell, 2016). Also, the environmental injustice associated with uneven access to green space is rarely considered in debates considering brownfield re-use; the most deprived (and potentially vulnerable to high temperatures) 10% of wards in England have five times less green space than the most affluent 20% of wards (CABE, 2010). This, combined with the broader quality-of-life benefits of soft-end brownfield conversions to local communities (De Sousa, 2006), emphasises the need to rethink the direction of brownfield redevelopment.

There may be opportunities to for greening of some of the brownfields in public ownership, as the NPPF leaves to the local authorities the task of ‘setting a locally appropriate target for the use of brownfield land’ (DCLG, 2012: 26). In addition, the possibility of housebuilding on green belt (the band of open space preventing urban sprawl, amounting to 13% of the England area, normally protected from development) is now cautiously being considered, in particular in areas of dire housing shortage and where the green belt land is of low quality (Future Spaces Foundation, 2014), which could lessen the pressure on brownfields somewhat. There are also potential barriers to brownfield development for hard-end uses, including the cost of site remediation and local infrastructure provision (CPRE, 2014), which may be less complex in the case of conversion to green spaces. The decision, which brownfield sites should be greened, from the climate adaptation perspective ought to be guided by the levels of social vulnerability and the exposure to high temperatures. To identify the scope for broader socio-economic and environmental benefits associated with the transformation of brownfield land to soft-end uses, GIS-based tools such as the long-forgotten Public Benefit Recording System (TEP, 2003) could be applied. Other non-statutory guidelines, such as Accessible Natural Greenspace Standard (English Nature, 2003), may help to identify where the most severe green space shortage is and highlight the brownfields in public ownership that could be converted to greenspace to address it.

Realistically, however, due to the ownership structure and housebuilding pressure, in the nearest future only a handful of brownfield sites is likely to be converted into dedicated green spaces, whilst the majority will be re-used as housing, offices or retail areas. Planning has a pivotal role to play in ensuring that any such development on brownfield land is adequately 'climate-proofed' (McEvoy et al., 2006). NPPF specifies that 'new development should be planned to avoid increased vulnerability to the range of impacts arising from climate change. When new development is brought forward in areas which are vulnerable, care should be taken to ensure that risks can be managed through suitable adaptation measures, including through the planning of green infrastructure' (DCLG, 2012: 23). International examples of regulations for incorporating greening into developments include the Biological Area Factor in Berlin, whereby a certain proportion of the site area needs to be greened (Kazmierczak & Carter, 2010) or the Green Points system in Malmö, Sweden, ensuring the quality of green cover (Kruuse, 2011). Toolkits for developers based on these guidelines start to emerge in the UK (GINW, 2010), but are by no means compulsory. Yet, established schemes rating the environmental performance of developments, such as BREEAM, also encourage incorporation of vegetation on site, as the ecosystem services provided by it correspond with many parameters that are measured, e.g. energy efficiency, water or land use and ecology (Dover, 2015). Application of these tools could result in greener developments providing cooling benefits, or not worsening the UHI effect and the risk of high temperatures to vulnreable communities.

In conclusion, re-using brownfields as green spaces could help to address the risks to human health associated with rising temperatures, as many previously developed sites coincide spatially with the communities vulnerable to climate change. However, the scope for widespread conversion of brownfield land into green space is limited due to the proposed use constraints, emphasis on urban densification and largely private ownership of sites. The role of planning in ensuring that brownfield redevelopment supports urban adaptation to climate change can be seen as twofold: identifying the sites for greening and encouraging incorporation of vegetation into new developments.

Acknowledgements:

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References:

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,* 245-255. doi:10.1016/j.ufug.2012.05.002

Bowler, D.E., Buyung-Ali, L., Knight, T.M., & Pullin, A.S. (2010) Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97,* 147-155. doi:10.1016/j.landurbplan.2010.05.006

CABE (2010) *Urban green nation: Building the evidence base*. London: Commission for Architecture and the Built Environment.

Carter, J., Cavan, G., Connelly, A., Guy, S., Handley, J., & Kazmierczak, A. (2015) Climate change and the city: Building capacity for urban adaptation. *Progress in Planning, 95,* 1-66. doi:10.1016/j.progress.2013.08.001

Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., … Patterson C. (2009) Managing the health effects of climate change. The Lancet, 373, 1693–733. doi:http://dx.doi.org/10.1016/S0140-6736(09)60926-0

Coumou, D., & Robinson, A. (2013) Historic and future increase in the global land area affected by monthly heat extremes. *Environmental Research Letters, 8(3)*, 1-6. doi:10.1088/1748-9326/8/3/034018

CPRE (2014) *From wasted space to living spaces. The availability of brownfield land for housing development in England.* London: Campaign to Protect Rural England.

DCLG (2012) *National Planning Policy Framework.* London: Department for Communities and Local Government.

DCLG (2013) *Land use change statistics in England: 2011*. London: Department for Communities and Local Government.

DCLG (2015) *2012-based household projections: England, 2012-2037.* London: Department for Communities and Local Government.

De Sousa, C.A. (2003) Turning brownfields into green space in the City of Toronto. *Landscape and Urban Planning 62,* 181–198. doi:10.1016/S0169-2046(02)00149-4

De Sousa, C.A. (2006) Unearthing the benefits of brownfield to green space projects: An examination of project use and quality of life impacts. *Local Environment, 11,* 577-600. doi:10.1080/13549830600853510

Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., … Faehnle, M. (2014) Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. *Journal of Environmental Management 146,* 107-115. doi:10.1016/j.jenvman.2014.07.025

Doick, K.J., Peace, A., & Hutchings, T.R. (2014) The role of one large greenspace in mitigating London's nocturnal urban heat island. *Science of the Total Environment, 493,* 662–671. doi:10.1016/j.scitotenv.2014.06.048

Dover, J.W. (2015) *Green infrastructure. Incorporating plants and enhancing biodiversity in buildings and urban environments.* Oxon: Routledge.

English Nature (2003) *Accessible green space standards in towns and cities: A review and toolkit for their implementation. English Nature Research Report No 526.* Peterborough: English Nature.

Future Spaces Foundation (2015) *Vital Cities not Garden cities: the answer to the nation's housing shortage?* Future Spaces Foundation.

Gill, S.E., Handley, J.F., Ennos, A.R., & Pauleit, S. (2007) Adapting cities for climate change: the role of the green infrastructure. *Built Environment, 33,* 115-133. doi:http://dx.doi.org/10.2148/benv.33.1.115

GINW (2010) *Green infrastructure (GI) toolkit*. Warrington: Green Infrastructure North West. Retrieved from http://www.greeninfrastructurenw.co.uk/climatechange/

HCA (2010) *National Land Use Database of Previously Developed Land (NLUD-PDL)*. London: Homes and Communities Agency.

HM Treasury (2015) *Fixing the foundations: Creating a more prosperous nation.* London: HM Treasury.

Kazmierczak, A. (2013) The contribution of local parks to neighbourhood social ties. Landscape and Urban Planning, 109, 31-44. doi:10.1016/j.landurbplan.2012.05.007

Kazmierczak, A., & Carter, J. (2010) *Adaptation to climate change using green and blue infrastructure. A database of case studies.* GRaBS, The University of Manchester, Manchester.

Klinenberg, E. (1999) Denaturalizing disaster: A social autopsy of the 1995 Chicago heat wave. *Theory and Society, 28,* 239–295. Retrieved from http://link.springer.com/article/10.1023%2FA%3A1006995507723

Kruuse, A. (2011) The green space factor and green points system. *Town and Country Planning Journal, 80,* 287-290.

Kuo, F.E., Sullivan, W.C., Coley, R.L., & Brunson, L. (1998) Fertile ground for community: Inner-city neighbourhood common spaces. *American Journal of Community Psychology,* 26, 823-851. doi:10.1023/A:1022294028903

Lindley, S.J, O'Neill, J., Kandeh, J., Lawson, N., Christian, R., & O'Neill., M (2011) *Climate change, justice and vulnerability*. York: Joseph Rowntree Foundation.

Longo, A., & Campbell, D. (2016) The determinants of brownfields redevelopment in England. *Environmental and Resource Economics (online), 1-23.* doi:10.1007/s10640-015-9985-y

McEvoy, D., Lindley, S., & Handley, J. (2006) Adaptation and mitigation in urban areas: synergies and conflicts. *Proceedings of the Institution of Civil Engineers Municipal Engineer, 159,* 185-191. doi:10.1680/muen.2006.159.4.185

McGeehin, M.A., & Mirabelli, M. (2001) The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States. *Environmental Health Perspectives, 109,* 185-189. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240665/

Mitchell, R., & Popham, F. (2008) Effect of exposure to natural environment on health inequalities: an observational population study. The Lancet, 372, 1655-1660. doi:http://dx.doi.org/10.1016/S0140-6736(08)61689-X

ONS (2005) *Horizons. The facts behind the figures. Issue 33.* London: Office for National Statistics.

Pauleit, S., Ennos, R., & Golding, Y. (2005) Modeling the environmental impacts of urban land use and land cover change – a study in Meerseyside, UK. *Landscape and Urban Planning,* 71, 295-310. doi:10.1016/j.landurbplan.2004.03.009

Polyakova, A. (2011) *Assessing the potential climate change adaptation functions of green spaces redeveloped from brownfields in Greater Manchester*. Manchester: University of Manchester.

Poumadere, M., Mays, C., Le Mer, S., & Blong R. (2005) The 2003 heatwave in France: Dangerous climate change here and now. *Risk Analysis*, *25*, 1483-1494. doi:10.1111/j.1539-6924.2005.00694.x

Robine, J.-M., Cheung, S.L.K., Le Roy, S., Van Oyen, H., Griffiths, C., Michel J-P., & Herrmann, F.R. (2008) Death toll exceeded 70,000 in Europe during the summer of 2003. *Epidemiology*, *331*, 171 – 178. doi:10.1016/j.crvi.2007.12.001

Smith, C.L., Webb, A., Levermore, G.F., Lindley, S.J., & Beswick, K. (2011) Fine-scale spatial temperature patterns across a UK conurbation. *Climatic Change, 109*, 269–286. doi:10.1007/s10584-011-0021-0.

Takano, T., Nakamura, K., & Watanabe, M. (2002) Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. *Journal of Epidemiology and Community Health*, *56*, 913-918. doi:10.1136/jech.56.12.913

TEP (2003) *The public benefit recording system. The development and application of a practical tool to assist prioritisation of reclamation investment.* Warrington: The Environment Partnership.

WMO (2015) *Provisional Annual Statement on the Status of Global Climate in 2015.* World Meteorological Organisation. Retrieved from https://www.wmo.int/media/content/wmo-2015-likely-be-warmest-record-2011-2015-warmest-five-year-period

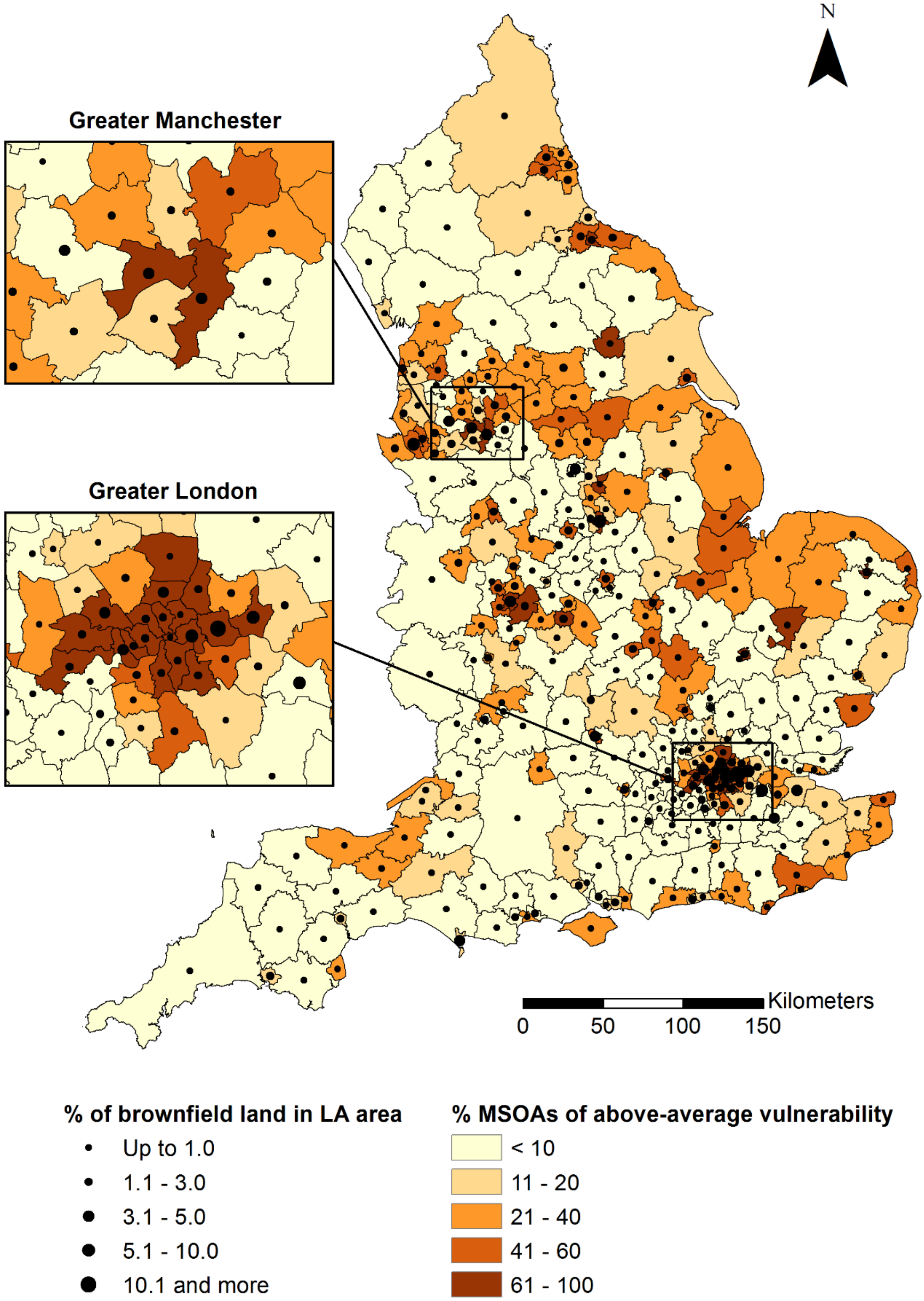

Figure 1. Percentage of MSOAs characterised by higher than average social vulnerability to high temperatures and proportion of the land classified as brownfield in the area of English local authorities. Data sources: climatejust.org.uk; HCA (2010). Base map is © Crown Copyright/database right (2015). An Ordnance Survey/EDINA supplied service.

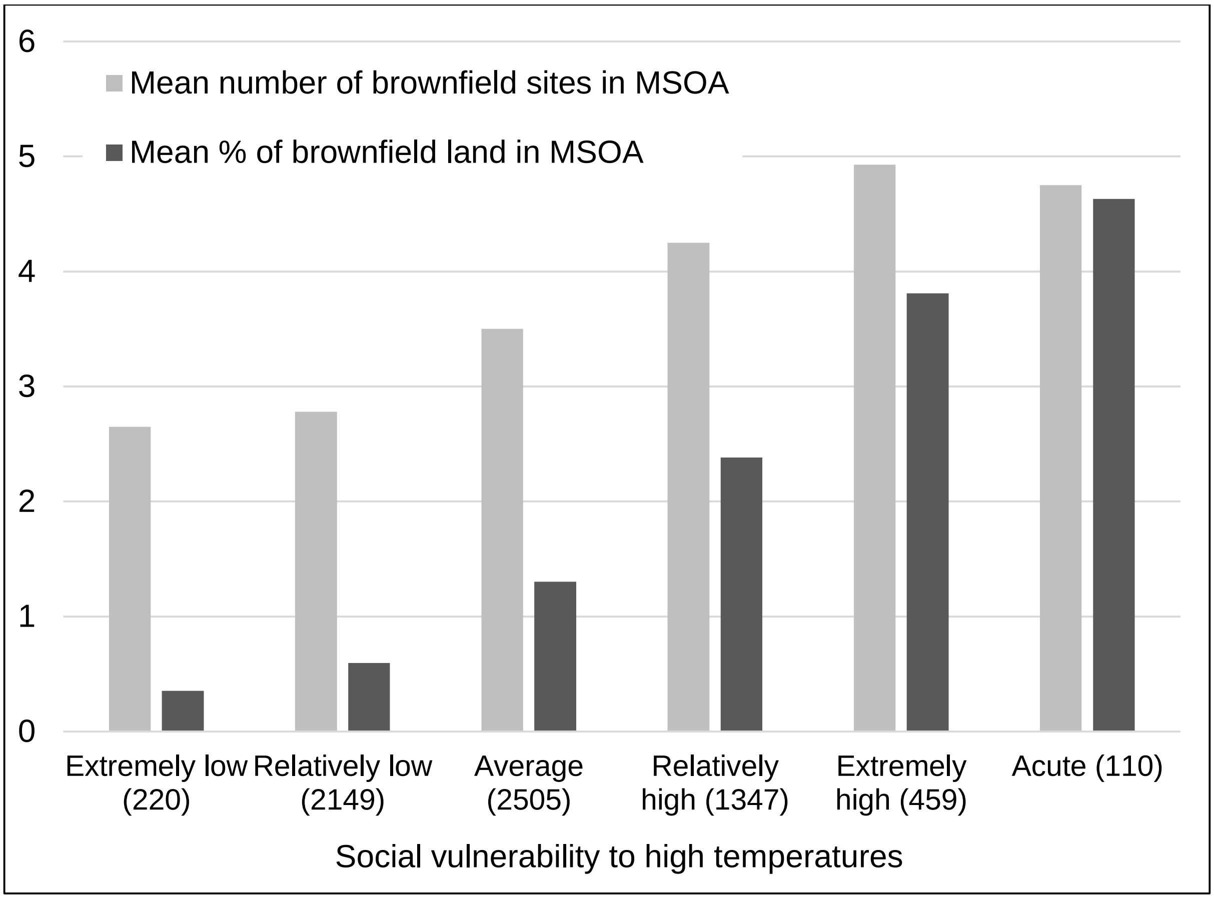

Figure 2. Association between the level of social vulnerability to high temperatures and the average number and area of brownfields in MSOAs.

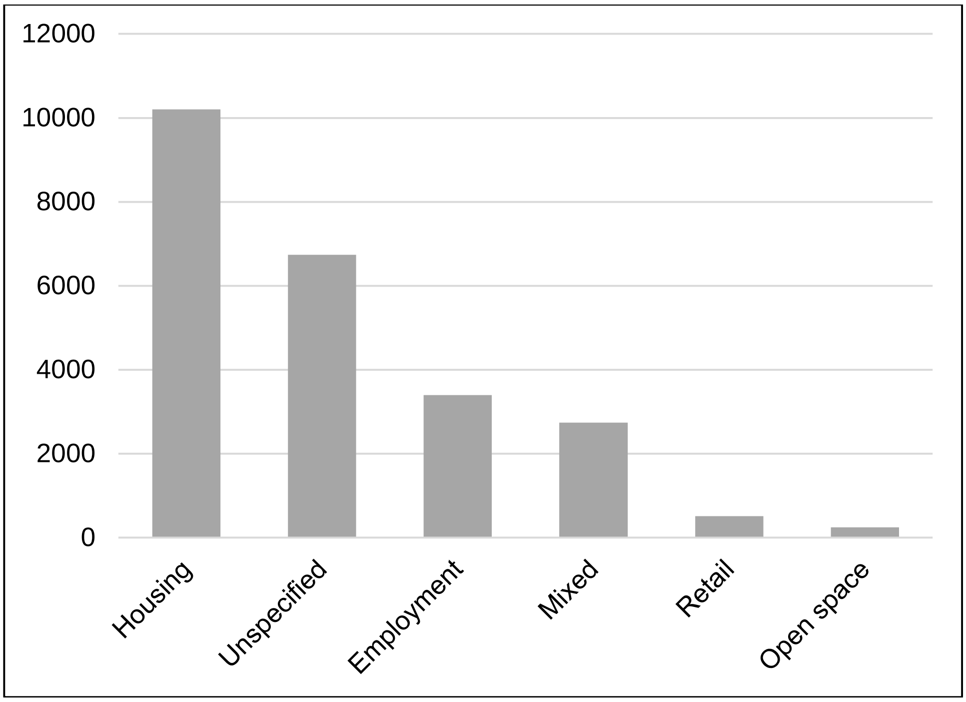

Figure 3. Proposed use of brownfields (number of sites).

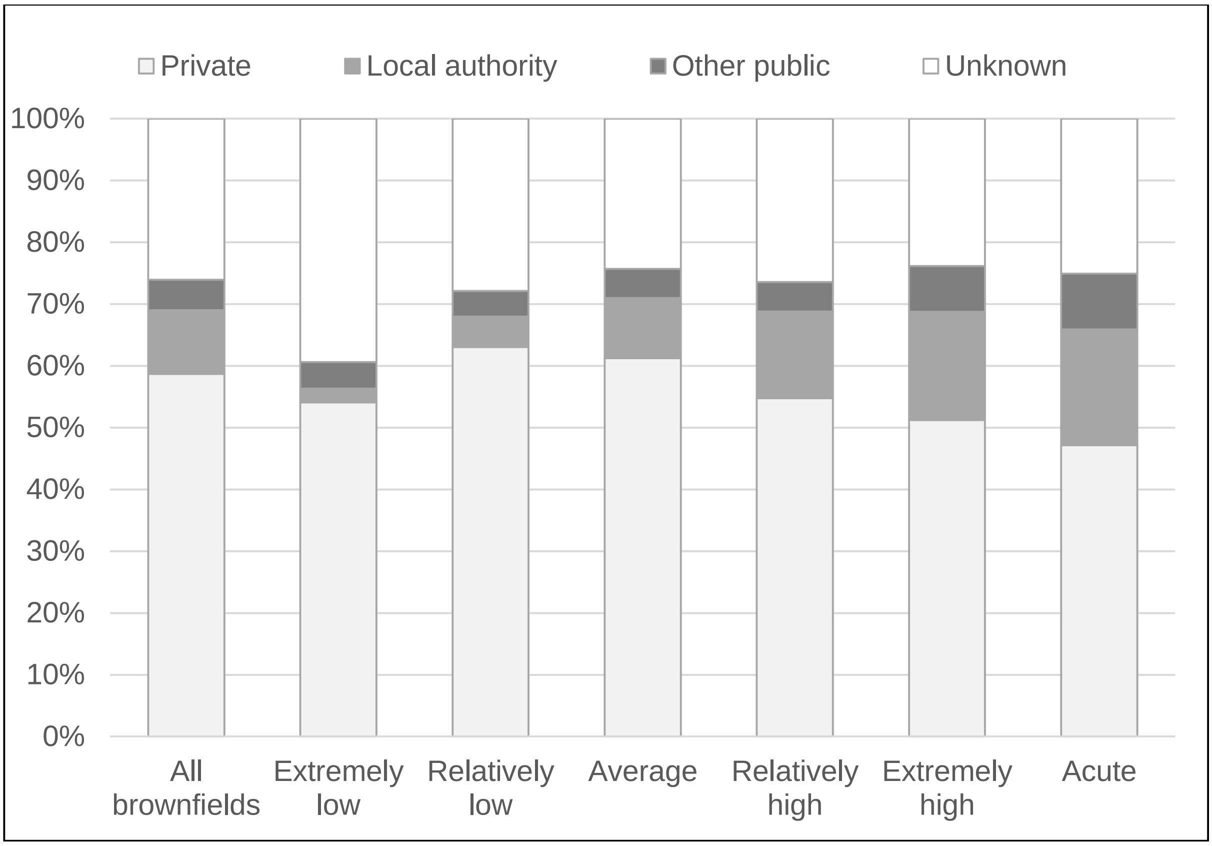

Figure 4. Ownership of brownfield land (number of sites by class of vulnerability of the MSOA they are located in).

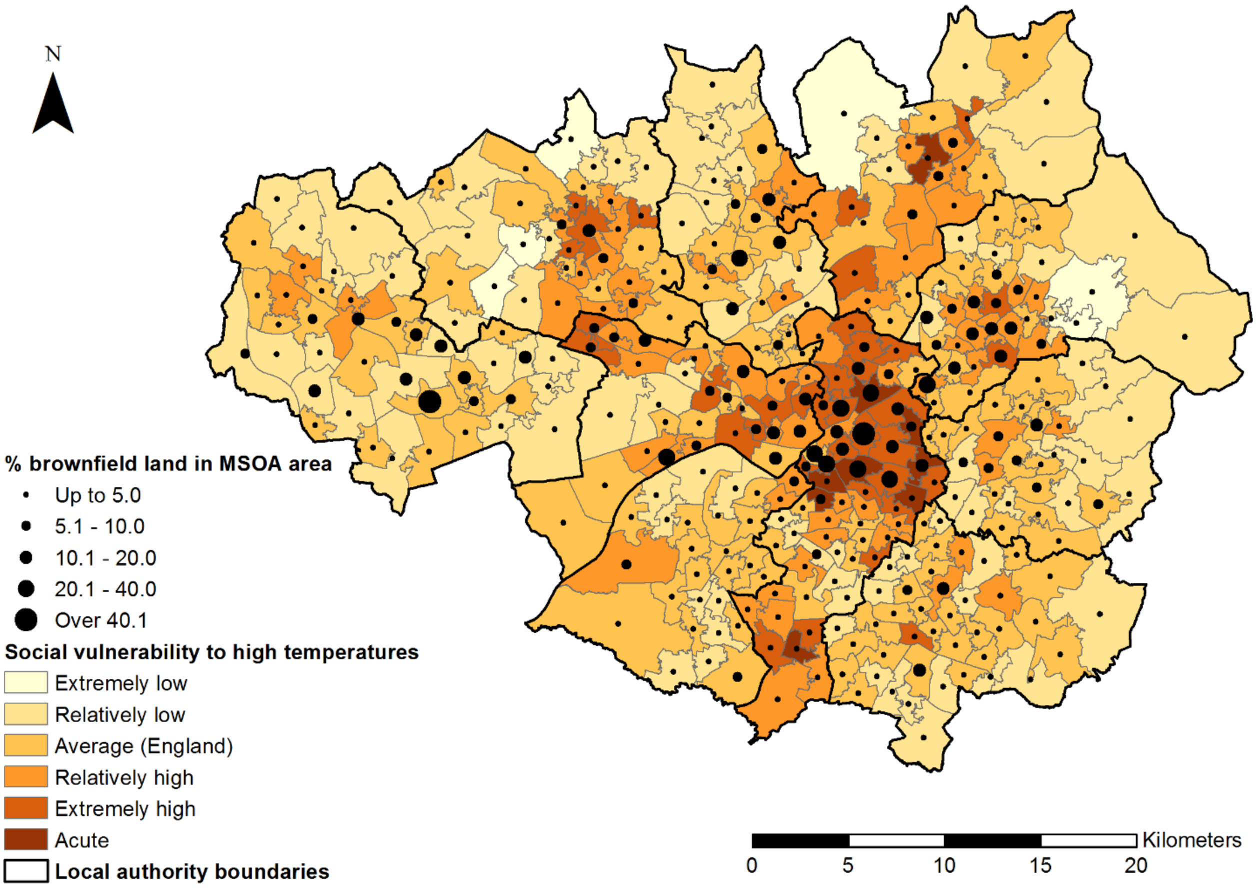

Figure 5. Social vulnerability to high temperatures (www.climatejust.org) and percentage of brownfield land (Polyakova, 2011) in Middle-layer Super Output Areas in Greater Manchester. Base map is © Crown Copyright/database right (2015). An Ordnance Survey/EDINA supplied service.

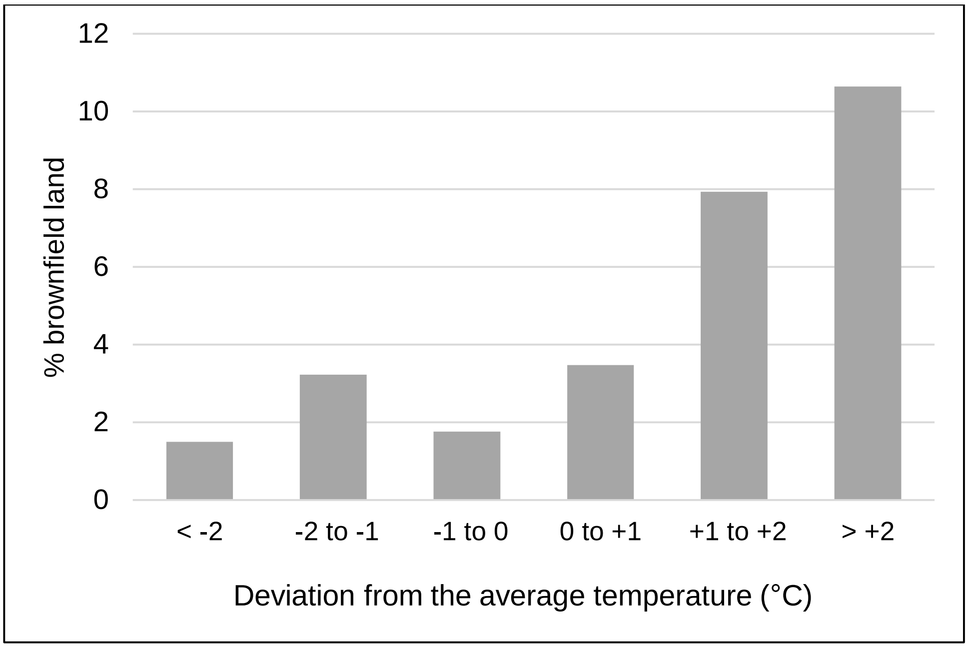

Figure 6. The area of brownfield land in relation to the intensity of UHI.

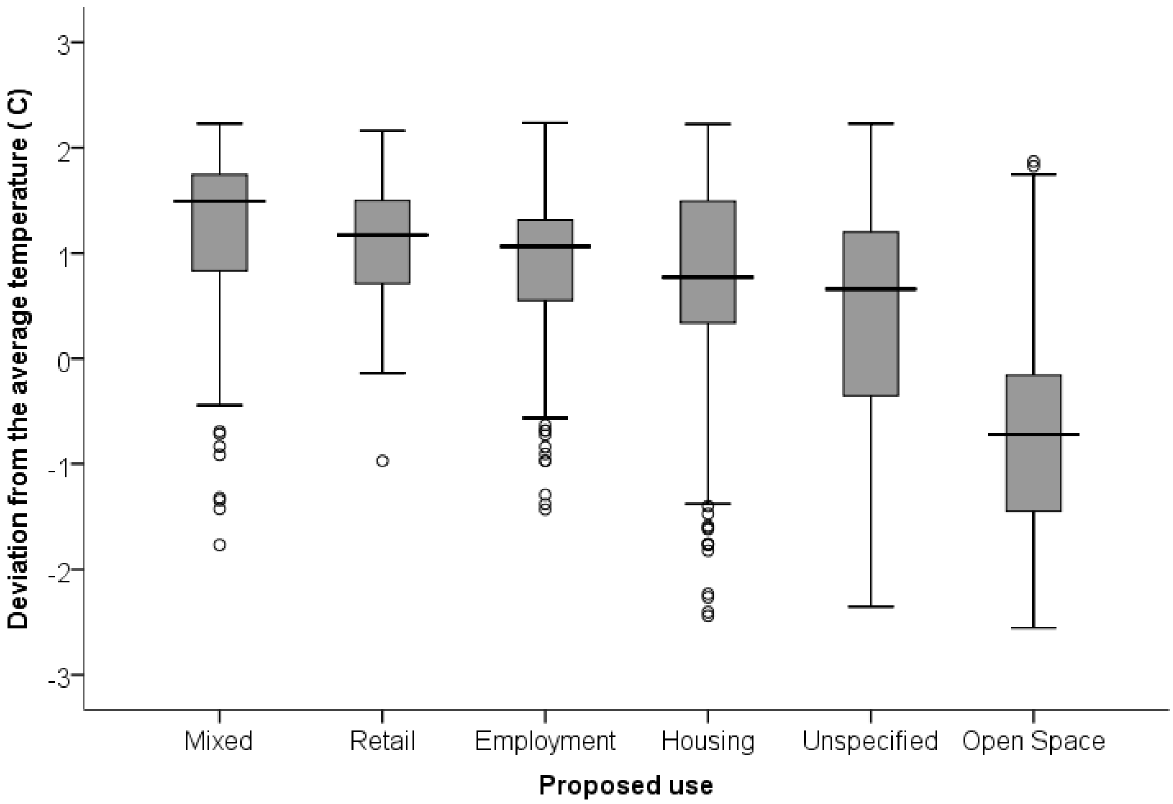

Figure 7. Temperature of the brownfield site (at its centroid) in relation to the proposed use of the sites. The boundaries of the box are Tukey's hinges. The median is identified by a line inside the box. The length of the box is the interquartile range (IQR) computed from Tukey's hinges. Values more than 1.5 IQRs but less than 3 IQRs from the end of the box are labelled as outliers (circle).