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Front gardens to car parks: Changes in garden permeability and effects on flood regulation

Jennifer R. Warhurst [a,1], Katherine E. Parks [a], Lindsay McCulloch [b,2], Malcolm D. Hudson [a,*]

[a] Centre for Environmental Sciences, Faculty of Engineering and the Environment, University of Southampton, Hampshire SO17 1BJ, United Kingdom
[b] Southampton City Council, Civic Centre, Southampton, Hampshire SO14 7LY, United Kingdom

HIGHLIGHTS

- Front gardens in urban areas have seen a change in land cover.
- This change is a shift from permeable to impermeable surfaces, for car parking.
- This amounts to an average of 22.47% of land area, over a twenty year period.
- Meanwhile the required attenuation storage volumes have increased by 26.23%.
- Our study indicates an increase in flood risk in known flooding hotspots.

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ABSTRACT

This study addresses the consequences of widespread conversion of permeable front gardens to hard standing car parking surfaces, and the potential consequences in high-risk urban flooding hotspots, in the city of Southampton. The last two decades has seen a trend for domestic front gardens in urban areas to be converted for parking, driven by the lack of space and increased car ownership. Despite media and political attention, the effects of this change are unknown, but increased and more intense rainfall, potentially linked to climate change, could generate negative consequences as runoff from impermeable surfaces increases. Information is limited on garden permeability change, despite the consequences for ecosystem services, especially flood regulation. We focused on eight flooding hotspots identified by the local council as part of a wider urban flooding policy response. Aerial photographs from 1991, 2004 and 2011 were used to estimate changes in surface cover and to analyse permeability change within a digital surface model in a GIS environment. The 1, 30 and 100 year required attenuation storage volumes were estimated, which are the temporary storage required to reduce the peak flow rate given surface permeability. Within our study areas, impermeable cover in domestic front gardens increased by 22.47% over the 20-year study period (1991–2011) and required attenuation storage volumes increased by 26.23% on average. These increases suggest that a consequence of the conversion of gardens to parking areas will be a potential increase in flooding frequency and severity — a situation which is likely to occur in urban locations worldwide.

1. Introduction

Domestic gardens are a key element of urban green space and are an integral part of urban environments (Gupta et al., 2012). Urban green space is open space within a city boundary with vegetation cover planted deliberately or inherited from pre-urbanisation vegetation (Jim and Chen, 2006), covering a mixture of landscape types including public parks, sports grounds and all natural areas inclusive of domestic gardens. Green space contributes to environmental regulation of, for example, atmospheric pollution, flooding, and urban temperature extremes; although in the UK there is generally a lack of information surrounding the extent of these contributions (Pauleit et al., 2005; Perry and Nawaz, 2008).

Domestic gardens were, until recently, considered a connection with nature, a statement of care, a source of escapism and a social amenity (Freeman et al., 2012). Increasingly, UK front gardens have undergone changes from manicured permeable green spaces to impermeable surfaces (Smith et al., 2011), primarily because of the potential to provide parking facilities for road transport network access, in the face of

* Corresponding author. Tel.: +44 2380 594797.
E-mail addresses: Jennifer.warhurst@atkinsglobal.com (J.R. Warhurst), K.E.Parks@soton.ac.uk (K.E. Parks), Lindsay.McCulloch@southampton.gov.uk (L. McCulloch), mdh@soton.ac.uk (M.D. Hudson).
[1] Present address: Atkins, Epsom Gateway, 2 Ashley Avenue, Epsom, Surrey KT18 5AL, United Kingdom. Tel.: +44 1372 726140.
[2] Tel.: +44 23 8083 3000.

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increased car ownership and restrictions in access to on-street parking. As a result urban green space is perceived to be declining, curtailing city dwellers' connection with nature and reducing the ecosystem services they deliver (Freeman et al., 2012; Perry and Nawaz, 2008). Economic growth has driven this change with UK car ownership increasing from 14% to 75% between 1951 and 2010 (Department for Transport, 2011).

Although attention to domestic garden permeability change has grown, the rate of change has scarcely been quantified (Smith et al., 2011). Quantification is necessary as urban domestic garden coverage has been estimated to account for between 19% and 27% of urban green space in cities and there are numerous associated effects of permeability change, including ecosystem service losses and increased flood vulnerability (London Assembly Environment Committee, 2005; Gaston et al., 2005).

1.1. Value of urban green space

Despite increased parking demand, residential green space has a value that should not be forgotten (Perry and Nawaz, 2008). Residential green space is increasingly viewed as a 'luxury' item (Cameron et al., 2012); throughout the 2000s there has been a clear trend to a higher density of new housing, with smaller areas of green space (Dunse et al., 2013).

Green spaces are urban assets which contribute to city residents'' quality of life, providing ecosystem services of increasing importance in the context of climate change such as flood regulation and temperature regulation (Farrugia et al., 2013). Ecosystem services, the terminology of which dates from the 1960s, are associated with ecological structures and processes which provide direct or indirect human benefits (Millennium Ecosystem Assessment, 2005). Urban green space, including domestic gardens provides a wide range ecosystem services, detailed as part of the UK National Ecosystem Assessment by Davies et al. (2011), yet little policy and legislation prevent their change to impermeable surfaces (Sayce et al., 2012).

1.2. Flood vulnerability

Surface water flooding is a hazard caused by heavy rainfall in urban environments (Kaźmierczak and Cavan, 2011). Impermeable surfaces increase surface water runoff and thus flood vulnerability (Kaźmierczak and Cavan, 2011), especially in urban city environments where they amass (Perry and Nawaz, 2008). Increased rainfall, potentially linked to climate change, is likely to result in more flooding events in these environments (Smith et al., 2009), and is a matter of current concern in the UK.

Recognition by local authorities (LAs) of flood vulnerability has improved with the development of surface water management plans (SWMPs — see below), so surface water flooding is a recognised risk in many UK cities (Kaźmierczak and Cavan, 2011; Perry and Nawaz, 2008). However, the question as to whether domestic garden permeability changes are intensifying the hazard has been the subject of limited research (Kaźmierczak and Cavan, 2011).

Green space presence reduces surface water flow rate and quantity through evapotranspiration, interception and the provision of temporary and permanent storage areas, enabling water to infiltrate the ground as opposed to entering drainage networks, which in the UK have been little modified since the Industrial Revolution, despite a six fold population increase (Ellis and D'Archy, 2002). Population growth has led to urbanisation, increased demand for urban living and affordable housing, typically with reduced garden sizes (Sayce et al., 2012). Furthermore, garden use is undergoing changes with the creation of dwellings in garden spaces, so-called "garden-grabbing" (Sayce et al., 2012). Urbanisation reduces garden size, and thus reduces urban green space, and alongside climate change presents a triple-edged sword for flood vulnerability and other ecosystem services (Perry and Nawaz, 2008).

An array of both 'quick fix' and long-term 'planning-based' solutions has been proposed and implemented to reduce flood vulnerability, both across the UK and globally (Swan, 2010). 'Quick fix' solutions are often preferred by financially constrained local councils and include in-sewer storage and sustainable urban drainage systems (SUDSs) (Swan, 2010). 'Planning-based' solutions include management of urban green space loss and extensive increases in drainage system capacity (Swan, 2010; Sayce et al., 2012). However, loss of urban green space, in the context of garden permeability change, despite the ecosystem services provided, is little considered or accounted for because it is largely unmanaged and unregulated (Perry and Nawaz, 2008).

1.3. Policy and legislation

The UK planning system has been accused of a slow response to the problem of garden permeability change (Boardman, 2003; Penning-Rowsell, 2001). This is thought to be mainly due to limited media interest which only began in 2004 (Perry and Nawaz, 2008), following the first report on the increasing proportion of impermeable domestic gardens in the UK prepared by the London Borough of Ealing (Healey, 2004). However, in light of increased housing demand and continuing urbanisation, the issue of garden permeability change has become politically contentious (Department for Communities and Local Government, 2010), especially due to the high rates of car ownership in Britain.

Domestic front or back gardens currently have no special status in planning law other than as part of private amenity space and are not classified as a land use in their own right (Department for Communities and Local Government, 2010; Sayce et al., 2012). and restrictions were eventually imposed in the National Planning Framework of 2012 (Sayce et al., 2012). However, the success of this is as yet unknown, and more local and national scale research is required to provide the evidence base for improved policy and legislation that will slow or halt the change of domestic gardens to impermeable surfaces (Perry and Nawaz, 2008).

1.4. Case study: Southampton

Southampton City's vulnerability to flooding was recognised by the 2011 SWMP (SCC, 2011). The SWMP was produced based on the requirements of the UK Floods and Water Management Act 2010 which established that unitary and county LAs would lead local flood management activities (SCC, 2011). A SWMP is a plan and report for surface water flooding, formulated through local partner and residential consultation, and analysis of historical and predicted flooding events. SWMP benefits include increased understanding of the location, likelihood and consequences of flooding, increased surface water flood planning, increased fulfilment of the requirements of the European Commission (2000), the Flood Risk Regulations (2009) and the Flood and Water Management Act (2010) and improved public engagement and understanding of surface water flooding.

The Southampton SWMP includes both fluvial (rising water levels in rivers and streams) and pluvial (overland flow generated by rainfall) flooding. The SWMP considered only surface water flooding (SCC, 2011): tidal and groundwater flooding were not considered as there are no high-risk groundwater areas within the city. Sixty flooding hotspots were included in the SWMP, including eight high-risk hotspots (Fig. 1), identified through the common risk rating approach (risk = severity * likelihood) using data from a variety of sources (Fig. 2) (SCC, 2011). A limitation with the Southampton SWMP is that the causes for flooding hotspots were not explicitly identified. Cause identification requires quantification and characterisation of land use change, along with estimation of the required attenuation storage volumes, and was a novel focus of this study.

Given the general increased public attention directed towards impermeable front gardens in relation to flood regulation, the limited evidence base calls for further research on this topic. Our aim is to quantify