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An investigation into the extent and impacts of hard surfacing of domestic gardens in an area of Leeds, United Kingdom

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Abstract

There is limited information available on the scale and potential impacts of increasing imperviousness in suburban areas, despite significant evidence which suggests that such changes could have severe consequences, particularly for urban flooding. In this investigation, aerial photographs from 1971 to 2004 were used to map changes in the impervious cover of a 1.16 km^2 suburban area of Leeds in northern England. A 13% increase in impervious surfaces was observed over the 33-year study period. Of the increase in impervious surfaces, 75% was due to paving of residential front gardens. To allow an assessment of annual runoff sensitivity to the increased imperviousness in the study area, an empirically based model, L-THIA (long-term hydrologic impact assessment model) was applied. The L-THIA hydrologic model predicts that average annual runoff increased by 12% over the period of study. The L-THIA model is also used to create a graph from which increases in annual runoff due to increased imperviousness can be predicted. These results show significant increases in imperviousness and suggest that this will cause an increase in the frequency and magnitude of flooding in the area.

Keywords: Impervious; Land-use; Urban; Flooding; GIS; Green space

1. Introduction

The extent of urban areas worldwide continues to grow from around 471 million ha, accounting for 4% of global land area (UNDP, 2000), due to population and housing pressures, employment and other socio-economic factors. In the UK, urbanisation has substantially increased since the middle of the last century and recent estimates indicate about 7% of England's land area is covered by cities and towns with populations exceeding 10,000 people (DETR, 2000). In the UK there is generally a lack of information on the extent of urban green space. This may in part be due to the fact that there is no statutory requirement for local authorities to provide good quality urban green space, and the issue therefore receives less attention (UK House of Commons, 2006). This should concern planning authorities given that numerous studies have demonstrated the high degree of sensitivity of important environmental responses (e.g. surface temperatures and stormwater runoff) to the extent of urban green space and building density (Pauleit and Duhme, 2000; Whitford et al., 2001; Nowak et al., 2003; Gomez et al., 2004).

There is even less information on the extent of domestic gardens in urban areas (Mathieu et al., 2007) yet they comprise a significant portion of many urban properties and must therefore constitute a sizeable proportion of urban areas (Daniels and Kirkpatrick, 2006; Gaston et al., 2005). The few studies attempting to quantify the extent of domestic garden coverage put the figure at 19–27% of the entire urban area (Owen, 1991; McCall and Doar, 1997; London Assembly Environment Committee, 2005; Gaston et al., 2005).

The positive effect of urban green space (including domestic gardens) on the health and well-being of city dwellers is well known (Dunnett and Qasim, 2000) but less well studied is the potential role of domestic gardens in alleviating urban flooding and aiding urban groundwater recharge. It is therefore important to accurately quantify the extent of green space within such envi-

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ronments (Gaston et al., 2005) and assess likely environmental impacts due to any changes.

In the UK, the high proportion of urban green space in some cities is now threatened by a relatively new phenomenon—the growing trend of paving over domestic gardens. Several reasons including increased car ownership, difficulty of on street parking, poor public transport and a fashion for low maintenance minimalist gardens have been identified as the likely causes (London Assembly Environment Committee, 2005). The practice of garden paving generally attracts little attention due to the small scale of each change but could have far-reaching consequences. Garden areas are beyond the scope of planning laws and are therefore often ignored by land use statistics and policies (Thompson et al., 2003; Gaston et al., 2004). This has caused widespread hard surfacing of gardens to remain undetected in many areas. Although the issue has been largely ignored until very recently, efforts are now underway to highlight the possible extent and impacts of domestic garden paving. For example two recent reports have highlighted the large increases in paving that have been occurring in London for many years (see London Assembly Environment Committee Report, 2005; Healey, 2004). The issue also received extended press coverage in the UK recently based on a warning from the British Royal Society for the Protection of Birds (RSPB, 2006).

The first published report on the subject of impervious front gardens in the UK prepared for the London Borough of Ealing (Healey, 2004) performed an extensive review of published research and found almost no information on the subject. Since the publication of this report, the London Assembly Environment Committee (2005) produced a desk study on paved gardens, sparking an increased interest in the subject. Also, Pauleit et al. (2005) provided an article with a brief discussion on urban garden paving in an area of northern England. Pauleit et al. (2005) used aerial photographs to measure land cover changes in the urban environment of eleven residential areas in Merseyside between 1975 and 2000. This was then followed by applying a simple hydrological model (adapted from Pandit and Gopalakrishnan, 1996), to determine runoff sensitivity to this change.

Given the general lack of studies on the topic, it is clear that further investigations on urban domestic gardens are required. The present study aims to fill this research gap by providing an assessment of the extent of domestic front garden paving and the resulting environmental implications for a small area of Leeds in northern England. This particular case study area was selected since it has experienced a large increase in the percentage of impervious surfaces over recent years and the investigation will attempt to explain any observed land use changes and implications for flood risk.

Over 100 urban runoff models of varying degrees of complexity are described in the literature (Mitchell et al., 2001) and these can be categorised into three groups (Nix, 1994); (i) simple models, (ii) simple routing models and (iii) complex routing models. As suggested by the name, the first type of model offers a simplified representation of the urban catchment and produce long-term averages (e.g. annual runoff); empirical models could be considered as simple models. Both simple and complex routing models are based on physical laws describing flow within a catchment (Zoppou, 1999). Although they are deterministic models, they describe catchment behaviour at different complexities (Zoppou, 1999). Given such large model choice, careful consideration needs to be given to model selection. Nix (1994) stresses that in urban runoff modelling, the key issue is to ensure a match between modelling effort and study objective—match the model to the task and avoid using a large model when a simpler, smaller one will suffice. Based on this recommendation, it was decided to employ a simple empirical runoff model in this investigation.

2. Methods

2.1. Study area

Research was undertaken for a 1.16 km^2 area of suburban housing, located in the suburbs of Halton, Austhorpe and Whitkirk (the areas fall within the Halton Ward according to the 2001 UK census classification) on the urban fringe of Leeds, in the county of west Yorkshire, England (Fig. 1). The majority of housing in the study area consists mostly of semi-detached bungalows with large gardens and space between bungalows to allow driveways to be constructed. There has been considerable urban densification in the last 40 years with a number of new housing and commercial developments being constructed. The Whitkirk conservation area is located within the study area.

The study area was selected due to an observed increase in the amount of impervious gardens in recent years, noted by Leeds City Council staff. The area was also subjected to serious flooding in August 2004, triggered by 3 h of heavy rainfall (Leeds City Council, 2004). At least 20 houses were inundated, some of which were rendered uninhabitable in the short term. Floodwaters are believed to have emanated from several sources including overland flow (Leeds City Council, 2004) but the main cause appears to be the inability of drains to cope with the volume of water travelling down the highway. In three parts of the study area large pools of water built up in 2004 causing inundation of nearby properties (see Fig. 1). A possible cause identified in the flood report by Leeds City Council (2004) is the paved driveways draining onto the road. An example of this is provided in Fig. 2 where the entire front garden is paved. In one case the flooding was made significantly worse by the fact that dropped curbs allowed floodwater to escape the gutter of the road and flow onto residential property, causing internal flooding of six bungalows. In June 2007, Leeds was again affected by flooding, and it was the Halton Ward once more which became one of the most badly affected areas. Repeated flooding has led to the Ward Councillor to call for urgent action to solve the problems of the flood-hit neighbourhood.

2.2. Calculation of impervious area

The total impervious area was calculated by mapping aerial photographs of the study area into the ArcMap GIS. In order to study the change in impervious surfaces over time, photographs taken in 1971 and 2004 were studied. The 1971 aerial