# LONDON: GARDEN CITY?

## From green to grey; observed changes in garden vegetation structure in London, 1998-2008

**Acknowledgements**
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This project was made possible thanks to a legacy left to The Wildlife Trusts by Dame Mary Smieton, an enthusiastic gardener and, in 1959, the second woman ever to lead a government department (education) in Britain.

**Reference**
Smith, C., Dawson, D., Archer, J., Davies, M., Frith, M., Hughes, E. and Massini, P., 2011. *From green to grey; observed changes in garden vegetation structure in London, 1998-2008*, London Wildlife Trust, Greenspace Information for Greater London, and Greater London Authority.

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A summary report *London: Garden City?* (Chloë Smith, 2010) is also available.

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# Introduction to project

## The importance of gardens

Gardens make up a significant amount of London's land cover. It is understood that this land is valuable for people and wildlife, and that climate change means it becomes even more important. But until now, the character and scale of this resource has not been fully documented.

Increasing attention is now being given to the role of private gardens in maintaining biodiversity in suburban and urban areas (Davies et al., 2009, Cannon *et al*., 2005, Gaston, *et al*., 2005a). Within London, gardens are a priority habitat for the London Biodiversity Action Plan (the Habitat Action Plan is being led on behalf of the London Biodiversity Partnership (LBP) by London Wildlife Trust) and a core habitat focus for London Wildlife Trust's *Living Landscapes* vision in the capital.

Concerns regarding the detrimental environmental impact of paving over front gardens have been highlighted by the Greater London Assembly and others (Greater London Assembly Environment Committee, 2005). Reflecting concerns about flooding, recent legislation changes have removed the right to pave front gardens (to an area greater than 5m$^2$) with traditional surfaces without planning permission or making adequate provision for drainage (Communities and Local Government, 2008). Anecdotal information and localised research (e.g. Ealing's Local Agenda 21 Pollution & Public Health Project Group, 2005) suggest that the vegetated area of gardens in London has decreased over time, mainly due to the loss of front gardens to paving to create parking areas, for convenience or 'cleanliness' and the loss of back gardens to built 'backland' development. However, no wide-reaching comparative study has yet been undertaken. There are also no current comprehensive data on the value of London's gardens for wildlife.

A lack of baseline information limits the possibilities of applying ecological knowledge to urban conservation planning (Niemelä, 1999; Miller & Hobbs, 2002). Baseline information about the garden resource in London is needed to inform policy and decision-making and provide a benchmark from which to measure change.

Perhaps more than any other green space categories, gardens fulfil multiple roles. They may provide a valuable wildlife habitat, a multifunctional space for people, and an environmental resource to cushion the likely impacts of climate change. They may also represent a significant leisure space and area for enjoyment of the outdoors and for the cultivation of plants; the expression of people's direct relationships with nature on their doorstep. However, gardens are different to other green space; land cover is highly heterogeneous and, being privately owned, gardens are subject to variable management.

An understanding of the current status and changing uses of gardens is of importance for conservation and planning policy makers within London. In light of this need, London Wildlife Trust, the GLA and Greenspace Information for Greater London (GiGL) commissioned this research project to establish the current use of London gardens and identify key land use changes over a period of 5-10 years.

## Aims of Project

The project aimed to generate a baseline of information regarding London's gardens to inform our understanding of their role for wildlife, people and the environment, to develop transferable methods of investigation, and interrogate some key lines of enquiry from stakeholders. In particular, the project aimed to: a) establish the current garden resource in London in terms of overall land use and variation within this; b) quantify the changes that have occurred to land cover within London's gardens over recent years and; c) provide evidence to focus campaigns, policy and other action to enhance gardens for wildlife.

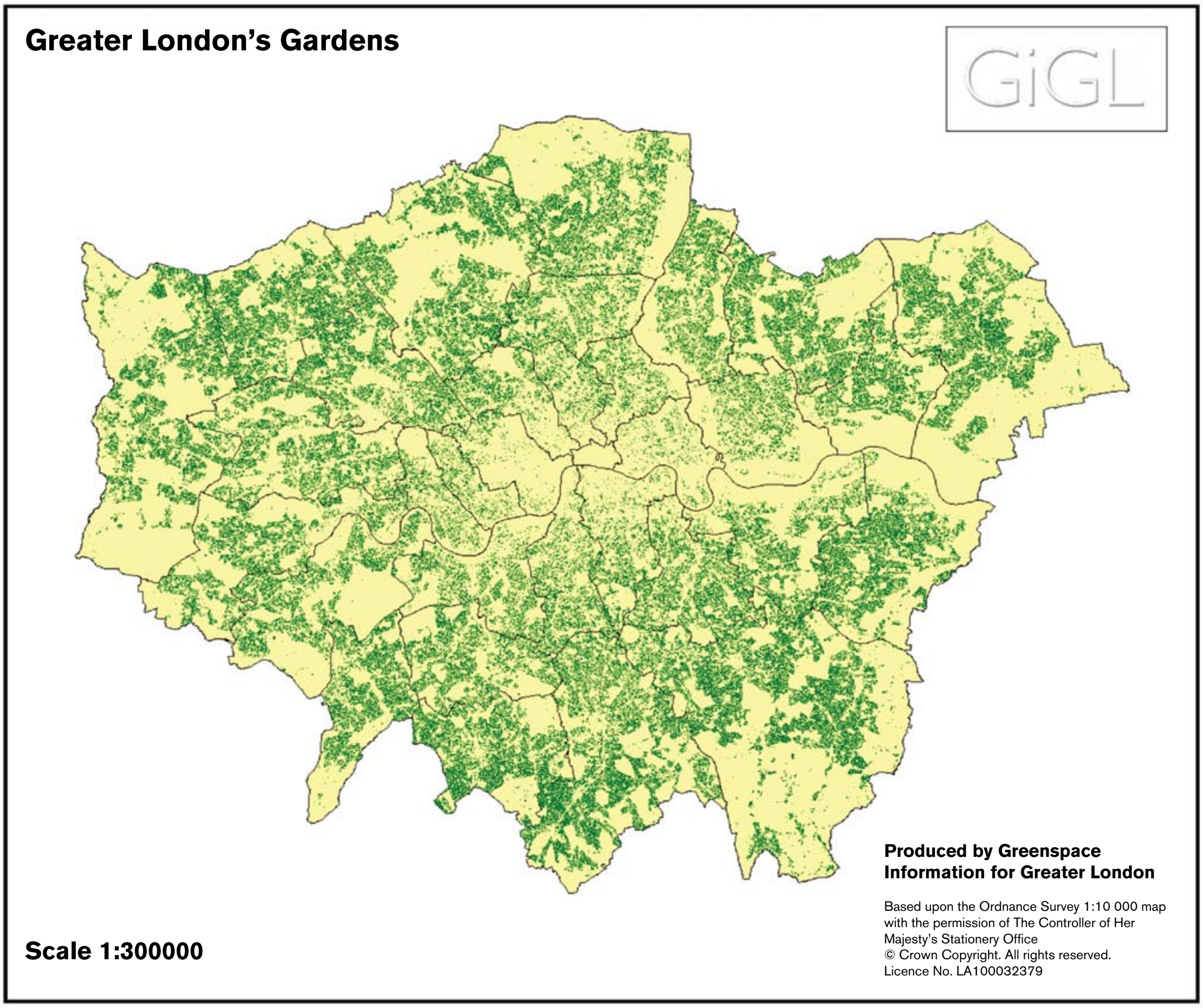
## Organisation of this report

The project report is divided into three chapters each documenting a stand-alone study that addresses a different line of enquiry with different methods. Many of the conclusions and recommendations are compatible and interlinked.

Study 1 documents a London-wide investigation of garden land cover. Here the project outlines the current baseline area and number of gardens in London and a typical garden's land cover composition. This study also addresses the key question of change over time in the vegetated component of gardens.

The second study reports an investigation of housing developments on garden land granted planning permission and implemented in recent years. This work reports the changes that occur as a consequence of this particular kind of development to the land that was originally garden and provides an estimate of the overall impact.

The third study reports the output of an exercise to identify priority areas for campaigning and advice regarding gardens and their roles for wildlife, people and the environment. This work demonstrates the ability of data based models to focus public engagement. It provides a working model and a baseline for further geographically based enquiry in the future.




# Study 1: Garden Land Cover

## Introduction

Greater London has 2.0 million dwellings which have an associated private garden, providing 3.8 million individual garden plots (counting front and back gardens separately). This makes a ground survey of a large enough sample of gardens prohibitively expensive in terms of resources and time. This study therefore used two series of colour aerial photographs of Greater London (Cities Revealed aerial photography ©The GeoInformation Group 2008) to determine the land cover present in a representative sample of London's gardens. The earlier photographs were taken between 1998 and 1999 and the later set was taken between 2006 and 2008.

Land cover measurements from the most recent photographs provide the best estimate of the current 'baseline' for London[1]. For example, the area covered by lawn, tree canopy or hard surfacing in a garden. Land covers were also recorded for each garden as it appears in the earlier series of photographs. This paired sample allows land cover change over time to be examined.

## Methods

Aerial photographs were stored and displayed in a Geographical Information System (GIS) (MapInfo Professional Version 9.5). Garden polygon boundaries from the Ordnance Survey MasterMap® Topography Layer data (updated June 2006) were used to define garden plots for the study (see **appendix 1.1** for information about this product). A polygon is the enclosed boundary around a topographical feature. A total of 3,267,174 polygons were identified as 'garden land' from MasterMap®. On inspection these were found to include: i) front garden plots ii) back garden plots, iii) gardens that due to position and shape were neither front nor back gardens and therefore termed 'other', and iv) polygons that comprised a front and back garden plot joined by a side passage or narrow strip of land. A number of polygons in each borough were exceptionally small and, on examination, were found to be due to mapping errors. Polygons less than 1m$^2$ were therefore removed from the GIS, resulting in 3,259,226 polygons.

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[1] Unless otherwise specified 'London' refers to Greater London, the area covered by the 33 administrative authorities including the City of London.

## Data categories

Land cover categories for gardens were defined and guidelines for their interpretation were developed following: a) trial analysis of garden polygons and exploration of the aerial photograph data, b) comparison of ground truth results to aerial interpretation, and c) consultation with stakeholders to address areas of interest. These categories are outlined in **table 1.1** and ground truth survey is detailed in **appendix 1.2**.

Aerial photograph interpretation allowed only broad land cover types to be recorded sufficiently well. Small features such as compost heaps or ponds could, unfortunately, not be detected with enough confidence.

Interpretation of the building category defined here requires a degree of caution. In this study, "buildings" exclude the dwelling (house, flat, bungalow etc.) and any other building as classified by MasterMap®, but are buildings within the garden plot visible on the aerial photograph, in most cases these are sheds and glasshouses. Some larger (footprint greater than 12m$^2$) garden outbuildings (and most garages) are classed as "building" by MasterMap® (Ordnance survey, 2009) and therefore are not included in the assessment of garden cover even when they are within the garden boundary.

Ideally, the building category used in this study would include all extensions to dwellings, as the effect of such smaller permitted developments (i.e. not requiring planning permission) is of interest, particularly given that they are not covered by the study of gardens subject to planning in the second chapter of this project. However, there is inconsistent inclusion of extensions in MasterMap® building polygons because of Ordnance Survey criteria and the age of the topographical layer used (see **appendix 1.3** for more detail). This limits final conclusions regarding the impact of specific kinds of building on gardens and points to a need for further work in the future (see recommendations for future work).

Tree canopy and lawn were readily identifiable. All other types of vegetation (hedges, climbers, small shrubs, herbaceous beds, rockeries, and wild areas) were classed together as 'other vegetation' (see **table 1.1** below).

| Land cover type | Definition |
|---|---|
| Tree canopy | A 'tree' refers to a mature woody species (or with a 2m wide canopy). No further distinction (e.g. between coniferous or deciduous) was made. |
| "Other vegetation" | Includes, small to medium sized (<2m wide) herbaceous or woody plants – flowers, shrubs etc. such as grown typically in a flower bed – scrub growth such as bramble cover, climbers such as ivy or wisteria and hedges. |
| Lawn | A grass/turf area. May be densely or sparsely vegetated, tall or closely mown. In this study lawn, also includes areas dominated by small ephemeral herbaceous plants. |
| Hard surfacing | Includes full spectrum of permeability e.g. paving, bricks, concrete, gravel or 'decking'. Includes patios, paths, steps and driveways. |
| Building | All sheds, glasshouses, summerhouses and other small (<12m$^2$) detached buildings, house extensions completed after June 2006 and some (unknown proportion of) extensions prior to this date (see appendix 1.3). |
| Side passageway | Narrow side path or passage along the side or between houses that is included within the garden polygon. Often shaded, but likely to be hard surface. |
| Other | Land cover type that is recognisable (i.e. not 'unknown') but doesn't fit into any of the broader categories. Typically, swimming pools, large compost heaps, garden debris, garden furniture and occasional large ponds. |
| Unknown | Area of garden that is obscured by deep shadow, poor photograph exposure or due to the photograph angle. |

**Table 1.1** – Land cover categories and definitions

## Sampling

Gardens to be examined on the aerial photographs were selected in accordance with a sampling strategy. This involved selecting a subset of garden polygons from the MasterMap® data isolated for London.

Sampling was stratified so that average land covers could be used to estimate total areas in London. A random sample of polygons was taken from each borough in proportion to the area of the garden plot polygons present. This was to ensure that the average in a given borough could be scaled up by the known garden area in each borough and that there was an adequate sample of the full range of garden sizes. As there were predicted to be relatively few large gardens and many small gardens in London this area based sampling also ensured there was adequate data on the larger gardens in each borough.

Gardens from each borough were included in the sample. There is variation in the number of gardens present in each borough. The borough samples were stratified in proportion to the number of garden polygons present in each. This had the effect of increasing the sample in those inner boroughs with many small gardens compared with those boroughs with many large gardens and increasing the sample in boroughs with large areas of built development compared with those boroughs with less built area.

The polygons proved to be of four kinds: i) front garden plots, ii) back garden plots, iii) gardens that were neither back nor front plots ("other" garden plots) and iv) front and back garden plots mapped as one combined polygon. In the latter case, where front and back plot were combined, the polygon was split into two, giving front and back gardens comparable to the first two kinds. This split was visually assessed and made in line with the rear of the dwelling.

The number of polygons selected from the whole of London with the stratification method was 1010, producing a sample of 1292 recorded garden plots after splitting of 282 polygons into their front and back components. In the rest of this report garden plot refers to the 1292 units i.e. those polygons not needing to be split, plus each of the two separate parts of those that were split.

## Corrections for bias

In order to make the sample representative of gardens throughout London, where necessary frequencies and means were calculated using estimates adjusted for known sources of bias in the sample.

Front and back garden plots formed from split polygons were selected on the basis of their combined area, which means they were over-represented in the sample. Therefore, for the analysis of trends and amounts it was necessary to give less weight to these gardens. Garden plots that were not split were given a weight of 1. Garden plots that came from a split were given a weight according to the proportion of the original polygon that they represent (both parts summing to 1). This not only allowed corrected garden plot areas to be calculated for these split front and back garden plots, but also allowed the over-representation of garden plots from split polygons to be corrected for overall percentages and means.

Estimation of the total number of front and back garden plots in London was complicated because we took an area sample in each borough and some of the selections were polygons that combined fronts and backs. Therefore, for overall estimates of front and back garden plot numbers we first estimated separately the number of front, back, and combined polygons in each borough, using an inverse weighting by the area of each polygon. It was then a simple matter to add the estimate of combined polygons to the fronts and also to the backs.

Because the sample between boroughs was in proportion to the number of garden polygons, borough statistics were weighted not by number but by the total garden area of a borough taken from MasterMap®. This means that each sample garden plot represented an appropriate area of garden from its borough when it came to scaling up estimates.

Post hoc inspection of the sample detected an over-representation of front gardens for terraced houses. An adjustment was therefore made to compensate for this bias, assuming equal numbers of front and back garden plots for terraced houses, in line with the pattern found for other house types. This had a minimal (one percentage point difference or less in most cases) effect on results, but was carried out for main numbers and areas reported.

## Recording of habitats and features

Proportions of different land cover types were estimated visually for each garden plot in the final sample. These proportions were to the nearest 5% - so that all land cover summed to 100% within an individual plot. This meant that it was only the uppermost layer in any multi-layered vegetation that was recorded, for example an area of lawn beneath a tree canopy would not be recorded. Other information of interest was also recorded for each garden plot. This included, plot type (front, back or 'other'), associated house type (detached, semi-detached, terraced or flat), the size of the garden plot and other notes.

Each garden plot was recorded twice, once for the earlier photographs (1998-99) and once for the later photographs (2006-08). Following data collection, results tables were examined and erroneous data entry mistakes corrected in MapInfo. Data were then exported to a Microsoft® Office Excel® 2007 spreadsheet and R 2.9.0 (*see www.r-project.org*) for further analysis.

## Quality control

Not all garden plots photographed were suitable for analysis. A check list was therefore designed to assess sampled gardens as suitable for study before land covers were recorded. Garden plots in which it was estimated that more than 20% of features were obscured due to: i) over-exposure or blur; ii) angle of the image; or iii) deep shadow, in either photograph were not included in further analysis.

To keep the sampling correctly in proportion to area within boroughs, rejected garden polygons were replaced by a polygon of equivalent size by selecting the next garden polygon in a cumulative list by polygon area. To arrive at the final sample, a total of 7444 polygons were rejected at the initial check list stage; an average of 7 rejects per recorded garden.

## Land cover area estimates

Estimates of garden plot percentage land cover from the most current records (2006-08) were used to estimate the most current baseline in London. The average percentage cover of each land category was calculated and this proportion was then applied to the total known area of garden in each borough (from MasterMap®) to estimate the overall area of a land cover.

Estimates were adjusted, as described above, to reflect the over representation of certain garden plot types in the sample from split polygons. And, calculations were implemented on a borough by borough basis and then combined to find the overall London figure to account for the differences in garden area between boroughs.

Area estimates of the total garden resource of London include all boroughs and all types of garden plot. For final figures and averages, the category of 'unknown' land cover was distributed between the different land cover categories in proportion, to obtain the best available estimate of the identity of these unknown areas. Raw area calculations including 'unknown' land cover are given in **appendices.1.8 and 1.9.** Calculations were also made for front, back and 'other' garden plots separately.

## Tree number estimates

The number of trees in garden plots was estimated by first calculating the tree density per plot as trees per square metre. This was then adjusted to correct for over-representation of garden plots from split polygons and over-representation of garden plots associated with terraced houses in the sample, as for area calculations. An average tree density per plot could then be calculated for every borough and applied to the total borough garden area to get the number of trees per borough. All borough numbers were then summed to get the overall London figure.

## Change analysis

Area estimates for differences between 1998-99 and 2006-08 were calculated in the same way as area estimates for London but using the difference in percentage land covers from the same garden plot over time. Changes were calculated for each garden and summarised for different types of garden separately.

Because the MasterMap® polygons were defined approximately at the same time as the most recent photograph series, it was not known how many garden plots had been totally lost. But it was possible to identify wholly new garden plots and a few of these (18) had been created. These were removed from the sample for the change analysis only to avoid bias resulting from including new gardens, but missing all total losses.

Paired t-tests were performed on transformed percentage land cover data (log+1 transformation) to examine the statistical significance of changes. The transformation was necessary to adjust the skew of the data towards normal distribution. Gardens with zero percentage cover values were removed for these tests, so they assess the significance of changes in gardens where a land cover was present.

## Confidence intervals

Whilst it would be informative for the main findings to be reported with their confidence intervals, the various biases and the great amount of skew in the distribution of garden sizes made this a technically difficult task. The reader may find it helpful, nevertheless to have an idea of the variation in the data as indicated by the standard error of the mean of the values that were summed to give the various estimates of total land cover area in London. These standard errors varied from 2% to 4% of the mean for the main land cover categories. Our confidence in the precision of the various estimates would be of this order, which is why the findings are reported to two significant figures, or the nearest percentage point.

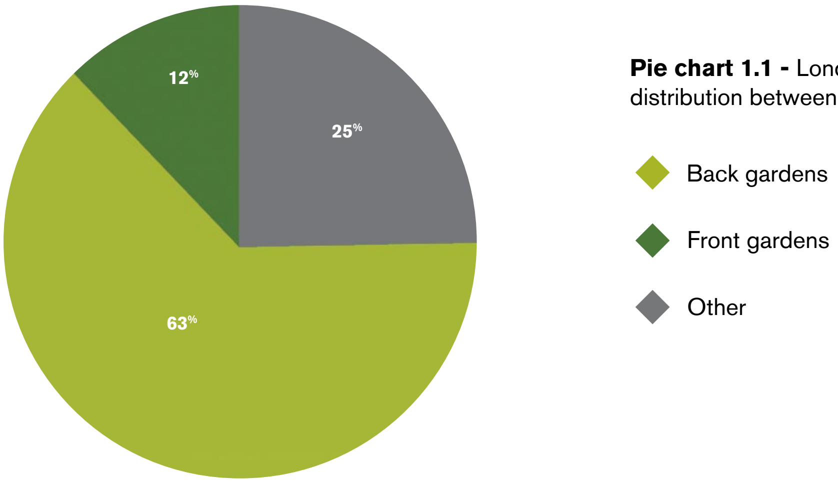
## Results; the current resource

### Number and area of private domestic gardens

The total number of garden plots as defined here in London is estimated to be about 3.8 million. There are roughly equal numbers of front and back plots, in the order of 1.8 million of each, with a smaller number (0.28 million) of 'other' plots. This means there are probably 2 million dwellings with associated private garden space. [Note: estimated results are presented to two significant figures throughout, in order to indicate precision].

The total area of garden in London is around 37,900 ha, which is approximately 24% of Greater London's total area (this is the figure from MasterMap®). Of course not all of this garden land is vegetated, see below. This study has found that back garden plots make up most of London's garden land, approximately 63% of the total garden area. Front garden plots contribute to most of the remaining garden land (approximately 25% of the total area). See **pie chart 1.1**.

Other types of garden plot were those that did not fit the traditional description of a front or back garden i.e. not predominantly situated at the front or rear of the house. These gardens often spanned an area around a block of flats, frequently including a communal parking area or lawn. These plots made up the final 12% of London's garden area (**pie chart 1.1**).




**Pie chart 1.1 -** London's total garden area (37,900ha) distribution between garden plot types

### Garden size

The mean front garden plot size in London is estimated to be 56m², back garden plots are much larger, a mean area of 150m² and other garden plots are even larger at an average 170m². Some other studies calculate the mean garden area associated with a single dwelling rather than considering fronts and backs separately. For meaningful comparison, an estimate of this average for a London dwelling with a front and back garden is the sum of the average front and average back garden plot areas, which gives an average garden area of 200m² per dwelling.

As anticipated, the size distribution of London's garden plots is highly skewed, meaning there are many smaller gardens compared to relatively fewer larger garden plots in London. The average garden plot size also varied six-fold between different boroughs, and even more if the City of London is included, shown in the **chart 1.1** below. Note: this graph includes measurements from both back and front garden plots separately so does not reflect the average area of garden per dwelling.

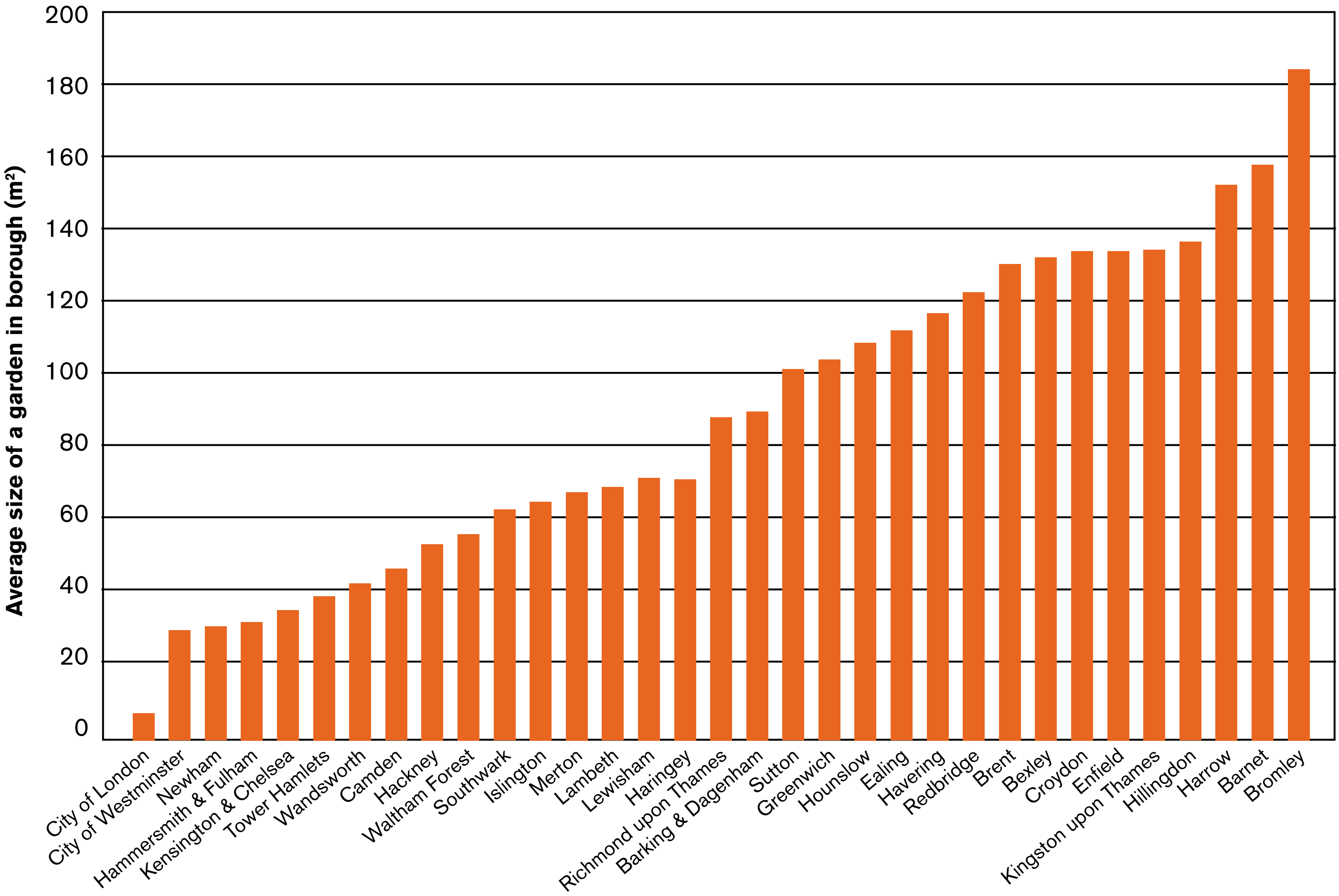



**Chart 1.1** - The average size of a garden plot ($m^2$) in each of Greater London's boroughs

## Garden plot size and type

The variables of garden plot size, plot type and house type were likely to be inter-correlated – for example, small garden plots may be more often associated with some types of house. To check this possibility a number of tests were performed.

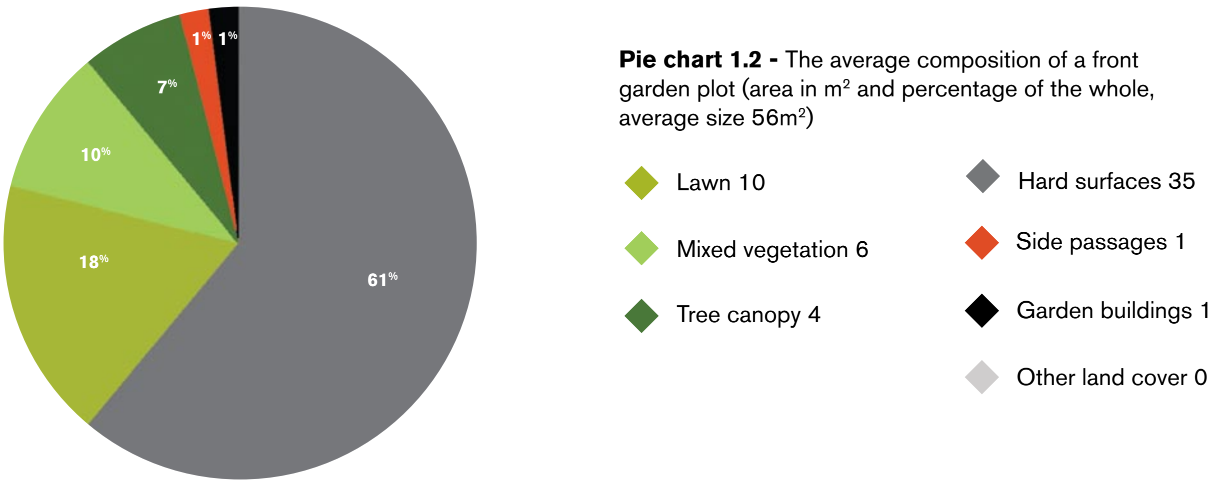
Garden plot area was significantly associated with the type of plot (ANOVA of log transformed garden plot area with garden plot type: $F = 174.1$, 2 and 1289 df, p-value: $< 0.0001$). For this reason much of the analysis in this study is performed for front, back and other garden plot types separately as well as for the total data set. It is also of more interest to a garden owner to give findings separately for front, back or other garden plots as they are likely ot be managed differently.

A contingency table was examined to assess the relationship between garden plot type and house type. It was found that there was a significant deviation from proportionate representation of each garden plot type in each house type category ($\chi^2 = 194$, df = 6, $p < 0.0001$). Cramér's statistic, which measures the strength of this association, was reasonably strong ($\phi = 0.274$). Most of this difference was accounted for by the number of 'other' garden plots, which are more common for detached houses and flats ($\chi^2 = 7.10$, df =1, $p = 0.008$ and $\chi^2 = 128$, df =1, $p < 0.0001$, respectively), and less common for semi-detached houses ($\chi^2 = 27.9$, df =1, $p < 0.0001$). Back garden plots were also less likely to be associated with flats than expected ($\chi^2 = 14$, df =1, $p = 0.0001$).

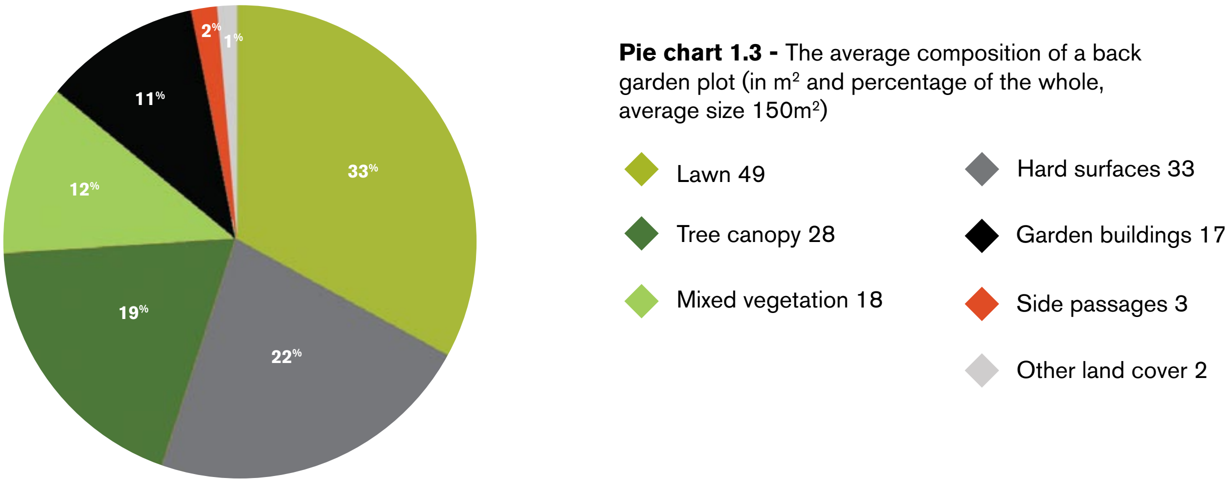
When only back and front garden plots were assessed, individual chi-square tests were not significantly different from even distribution and $\phi$ was reduced to 0.095 by the exclusion of the other garden plots. So the proportions of front and back garden plots in the sample had little association with house type, not varying greatly. 'Other' garden plots were an exception, being frequently associated with flats.

## Average garden composition

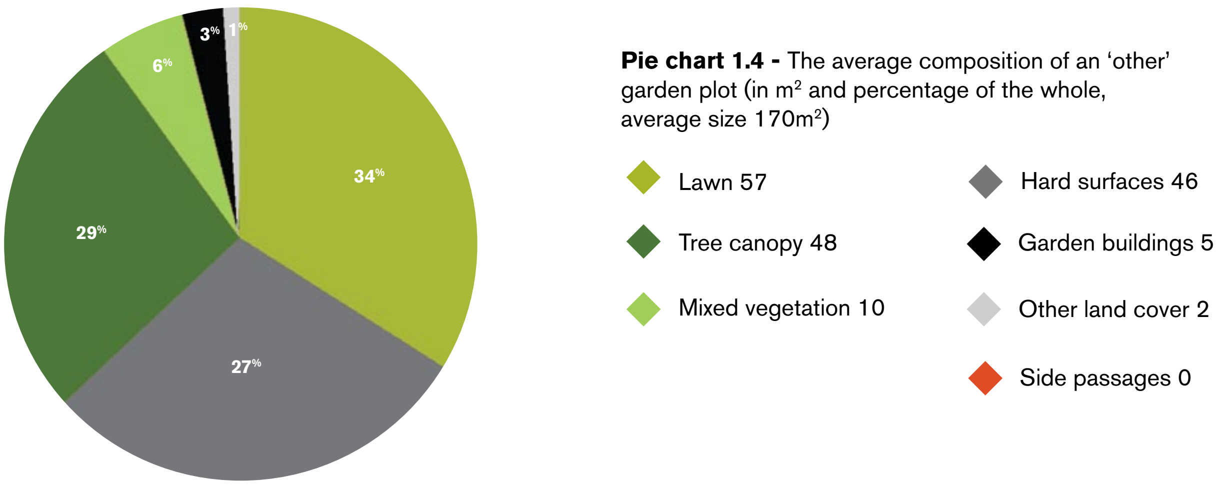
The average amounts of land cover types calculated from the sample (following appropriate adjustments) are shown in **pie charts 1.2, 1.3 and 1.4** below. It is most notable that on average front garden plots are mostly covered by hard surfaces (average of 63%) with relatively small proportions of lawn, mixed vegetation and tree canopy. An average back garden plot is more varied in its composition. Typically, back garden plots have a large area of lawn (average proportion of 33%) and a relatively large area of tree canopy and mixed vegetation compared to front garden plots. Hard surfacing still appears to be important in back garden plots, with an average of 22% cover. The average 'other' garden plot is similar to a back garden plot, with the exceptions of a larger proportion of hard surface cover and a somewhat larger proportion of tree canopy cover. There is, on average, one tree for every back garden plot and one tree for every 'other' garden plot (1.1 and 1.0 trees per back or other garden respectively). Trees are less common in front gardens, one present on average in every fifth front garden (0.2 trees per front garden) garden plots (see **appendix 1.7**).




**Pie chart 1.2 -** The average composition of a front garden plot (area in $m^2$ and percentage of the whole, average size $56m^2$)



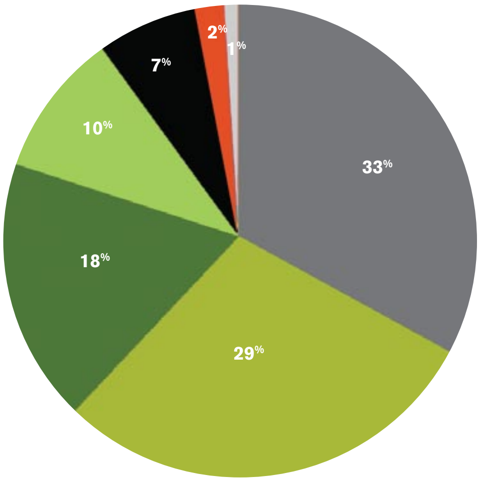

**Pie chart 1.3 -** The average composition of a back garden plot (in $m^2$ and percentage of the whole, average size $150m^2$)




**Pie chart 1.4 -** The average composition of an 'other' garden plot (in $m^2$ and percentage of the whole, average size $170m^2$)

## Total land cover areas

When averages are scaled up to London, the total area of vegetated land cover (lawn, tree canopy and mixed vegetation) in London's gardens is approximately 22,000 ha. This is 57% of the total garden land resource of London. There are estimated to be 2.5 million garden trees in London (**appendix 1.7**). The **pie chart 1.5** below illustrates the proportions of different land covers that make up the total 37,900 ha of London garden land; these are also listed in **table 1.2**.




**Pie chart 1.5 -** Total percentage of land cover categories, estimated for the 37,900 ha total garden space of London in 2006-08.



Analysed separately, it can be seen how different types of garden contribute to the total areas of garden land cover types in London. These results are also shown in **table 1.2** on page 14. Front garden plots in London contribute to a large area of hard surfacing. Back gardens contribute most significantly to the total garden vegetated land cover, or green space, in London. Back garden plots include about 1.9 million garden trees, front gardens 0.4 million garden trees and other garden plots 0.3 million garden trees (**appendix 1.7**).

| Land cover type | Total area (ha) | % of garden area | % of London | Total area in Front garden plots (ha) | % of front garden plot area | Total area in back garden plots (ha) | % of back garden plot area | Total area in 'other' garden plots (ha) | % of 'other' garden plots area |
|---|---|---|---|---|---|---|---|---|---|
| **All land** | 37900 | 100% | 24% | 9400 | 100% | 24000 | 100% | 4600 | 100% |
| Tree canopy | 6700 | 18% | 4% | 740 | 8% | 4600 | 19% | 1300 | 28% |
| Lawn | 11000 | 29% | 7% | 1630 | 17% | 7900 | 33% | 1500 | 33% |
| Mixed vegetation | 4000 | 11% | 3% | 930 | 10% | 2800 | 12% | 280 | 6% |
| **Total 'green' land covers** | **22000** | **58%** | **14%** | **3300** | **35%** | **15000** | **63%** | **3100** | **67%** |
| Hard surface | 13000 | 34% | 8% | 5900 | 63% | 5300 | 22% | 1300 | 28% |
| Buildings | 2800 | 7% | 2% | 120 | 1% | 2600 | 11% | 140 | 3% |
| Side passage | 590 | 2% | <1% | 100 | 1% | 480 | 2% | 10 | <1% |
| Other | 340 | 1% | <1% | 10 | <1% | 280 | 1% | 50 | 1% |

**Table 1.2** - Total areas of land covers estimated to be present in London's garden plots in 2006-08 (2 s.f.) and associated percentages. Also given for front, back and other types of plot. (Areas scaled up from sample and 'unknown' land cover proportionally distributed amongst other categories). Standard errors of raw figures were of the order of 3% for the main categories

## Variation in London's garden plots

### Garden plot type and land cover

The percentage cover of several different land cover categories differed between front, back and other types. Several of these differences in percentage land cover were found to be statistically significant in Kruskal Wallis rank sum tests (tree canopy $\chi^2$= 147, df = 2, p-value < 0.0001; lawn $\chi^2$= 159, df = 2, p-value < 0.0001; mixed vegetation $\chi^2$= 38, df = 2, p-value = < 0.0001; hard surfacing $\chi 2$= 364, df = 2, p-value < 0.0001 and building $\chi^2$= 282, df = 2, p-value < 0.0001). This means that the three different types of garden plot differ in terms of their garden composition, as illustrated by **pie charts 1.2 - 1.4**. This is also likely to be related to the different sizes of garden types, see next section.

### Garden plot size and land cover

The amount of some land covers was correlated with garden plot area. The percentage covers of hard surface, buildings and mixed vegetation decreased as garden plot area increased. This means that these land covers tend to occupy a smaller proportion of larger garden plots than smaller garden plots. The Pearson product moment correlation coefficients were all highly significant: hard surface r -0.23, df 1146, buildings r -0.14, df 431, mixed vegetation r -0.14, df = 841.

There was also a negative correlation between the percentage unknown land cover and garden plot area

(Pearson product moment correlation coefficient r -0.10, df = 929). This declining percentage of unknown land cover with increasing garden area is likely due to shadows from walls or the building covering a proportionately larger area in a small garden plot compared to a large garden.

The percentage cover of tree canopy and of lawn did however increase with increasing garden plot area. Although these increases were not statistically significant, some land cover must increase, given the significant decreases documented above and that the percentages add up to 100.

Apart from these changes in the amounts of any particular cover type, small garden plots were more likely to lack some elements of cover. As a result of this, the number of cover types increased significantly as garden plot size increased. This is also likely to be related to garden type, as described above. It may be that equivalent areas made up of large garden plots and/or back gardens have a richer variety of habitats than if they were made up of small garden plots and/or front gardens.

## Change in garden composition over time

### Observed changes in area of land cover

Over the time period studied, there were a number of notable changes in the different land cover types of London's gardens. The total area values for 1998-99 are given in **appendix 1.4**. Changes over the 8.5 years (on average) in the areas of land cover are illustrated in the graph below and tabulated in **appendix 1.5**.

Hard surface showed the biggest gain, increasing in cover by 2,600 ha over the time period, which is an increase of 26% on the original area of hard surface in 1998-99. Lawn showed the largest reduction in area, decreasing by 2,200 ha, down 16% of the 1998-99 amount. All vegetated land (lawn, tree canopy and other vegetation) decreased in total area over time. Overall, the area of vegetation was reduced by 3000 ha, a 12% drop on the 1998-99 area of vegetation, see **chart 1.2**. A number of changes over time in land cover types (tests on raw data before unknown areas proportionally distributed) were statistically significant (analysis results are given in **appendix 1.6**).

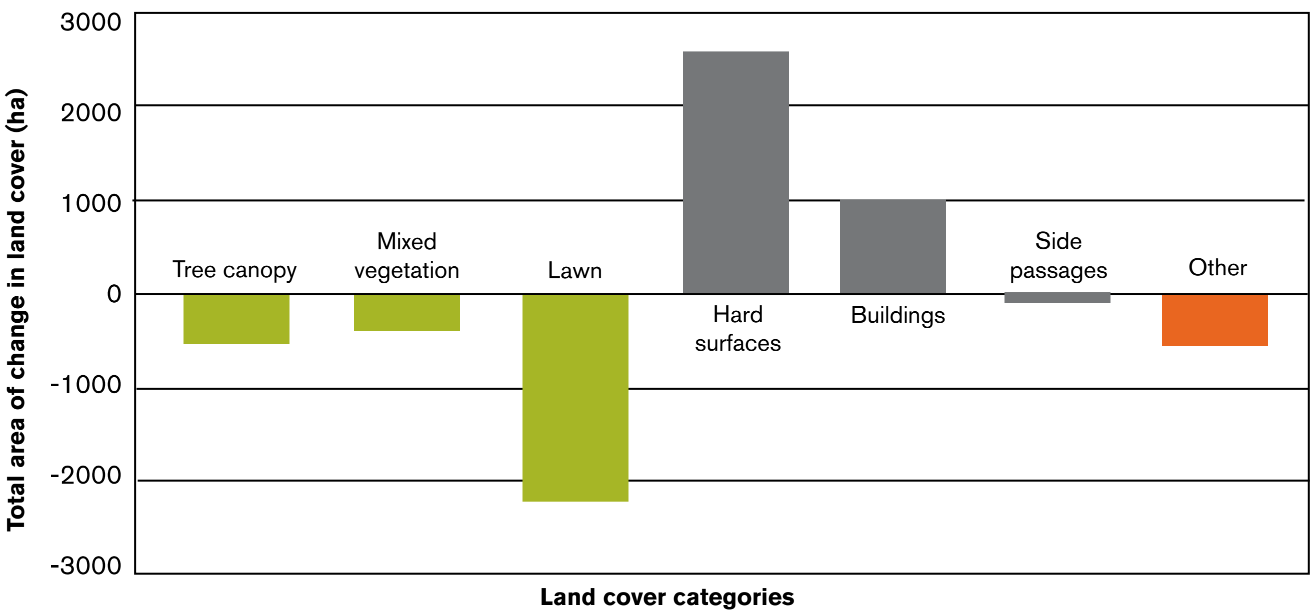



**Chart 1.2** - Change in area of land cover categories (ha) for all garden between 1998-99 and 2006-08 (unknown land cover distributed proportionally between known categories)

When different garden plot types are examined separately, similar trends of land cover change emerge for each type but with varying magnitude. Changes in lawn and hard surfacing are common for all garden plot types, with an increase in garden buildings also notable for back garden plots, see **appendix 1.5**.

In front garden plots, the largest changes in percentage land cover were a decrease in lawn and a parallel increase in hard surface. Both of these land covers were significantly different between the two time periods. Mixed vegetation and tree canopy showed smaller decreases in coverage and buildings showed a small increase in coverage (which were not significant over this time period). These major land cover trends are illustrated in **chart 1.3** below. The unknown percentage area cover also showed a significant reduction between the two sets of photographs, probably because the second set of photographs were of higher quality.

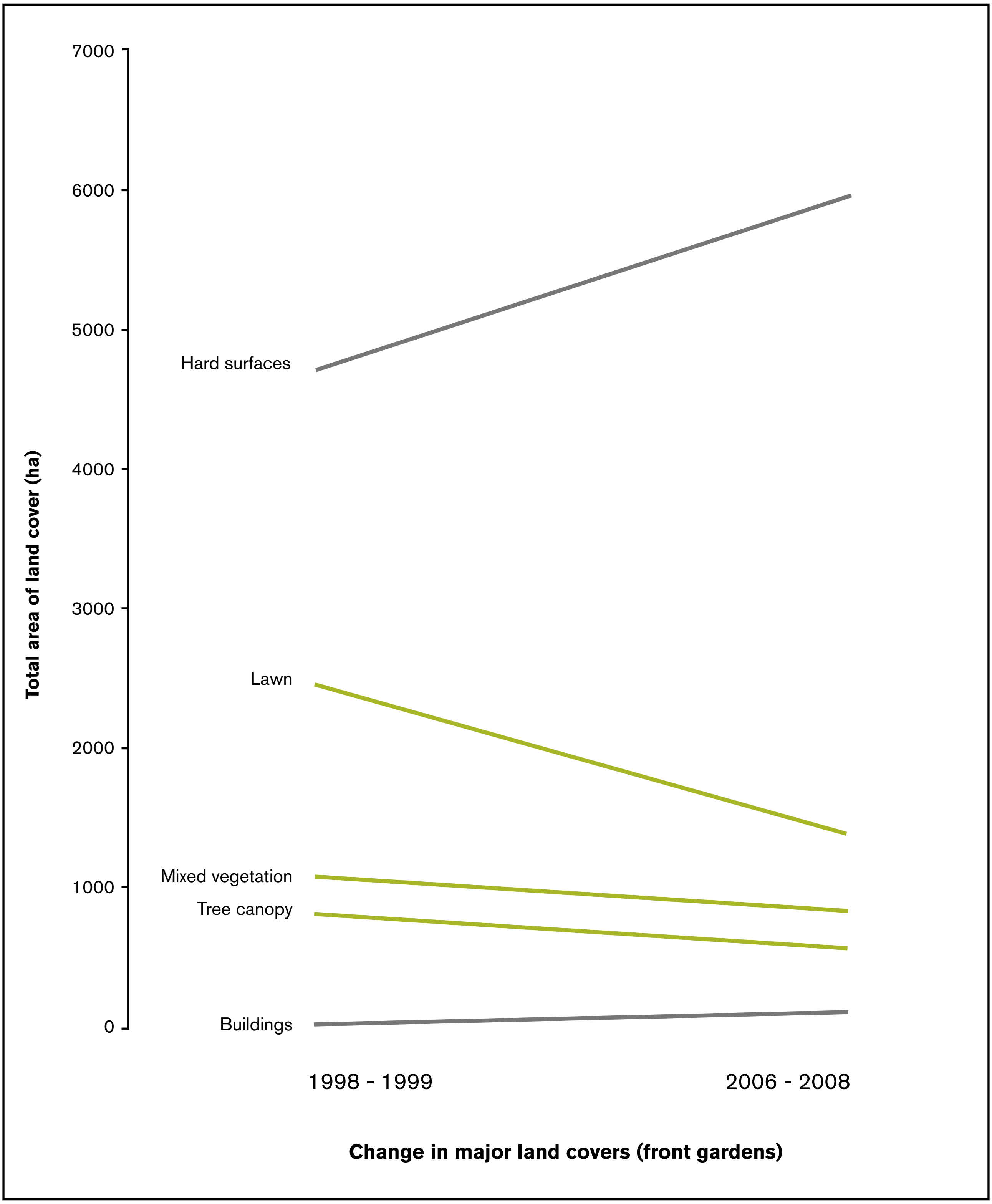



**Chart 1.3** - changes over 8.5 year study period in the total area of various land covers found in front garden plots

In back garden plots, similarly to fronts, there was a significant decrease in percentage cover of lawn and a significant increase in hard surface. Unlike front garden plots, for backs an increase in the cover of buildings was also important. Other vegetation and tree canopy decreased in percentage cover, but this was not statistically significant over this time period. Major trends are illustrated in **chart 1.4**. Back garden plots also showed a significant reduction in unknown percentage area cover between the two sets of photographs.

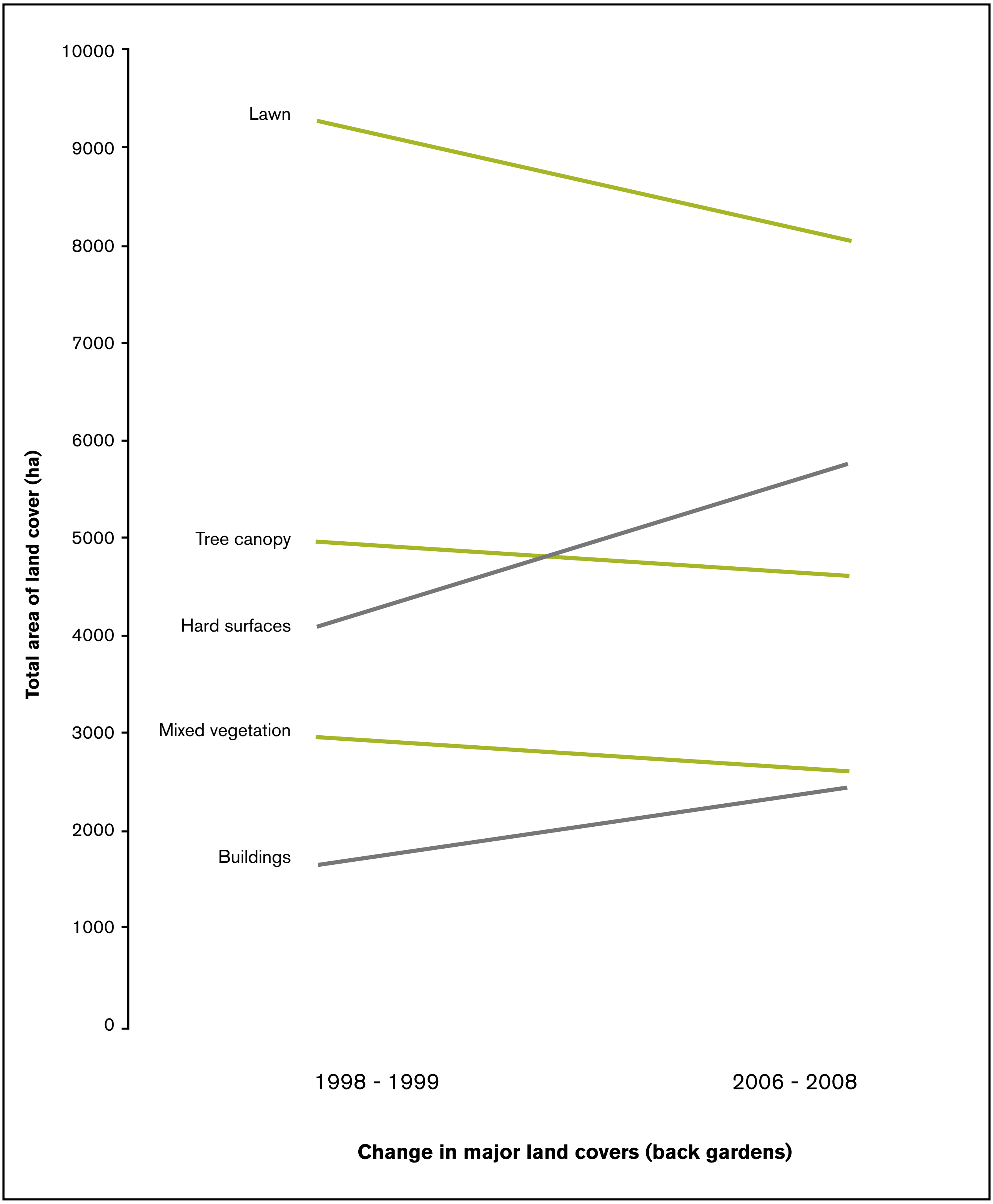



**Chart 1.4** - changes over 8.5 year study period in the total area of various land covers found in back garden plots

In ‘other’ garden plots, lawn showed a significant reduction in percentage cover over the time period. There were also large changes in estimates of percentage cover of hard surface and tree canopy cover, although these trends were not statistically significant. Other vegetation and buildings cover remained very stable. These changes are shown in chart 1.5. The change in unknown land covers over time was also not significant in this type of garden plot.

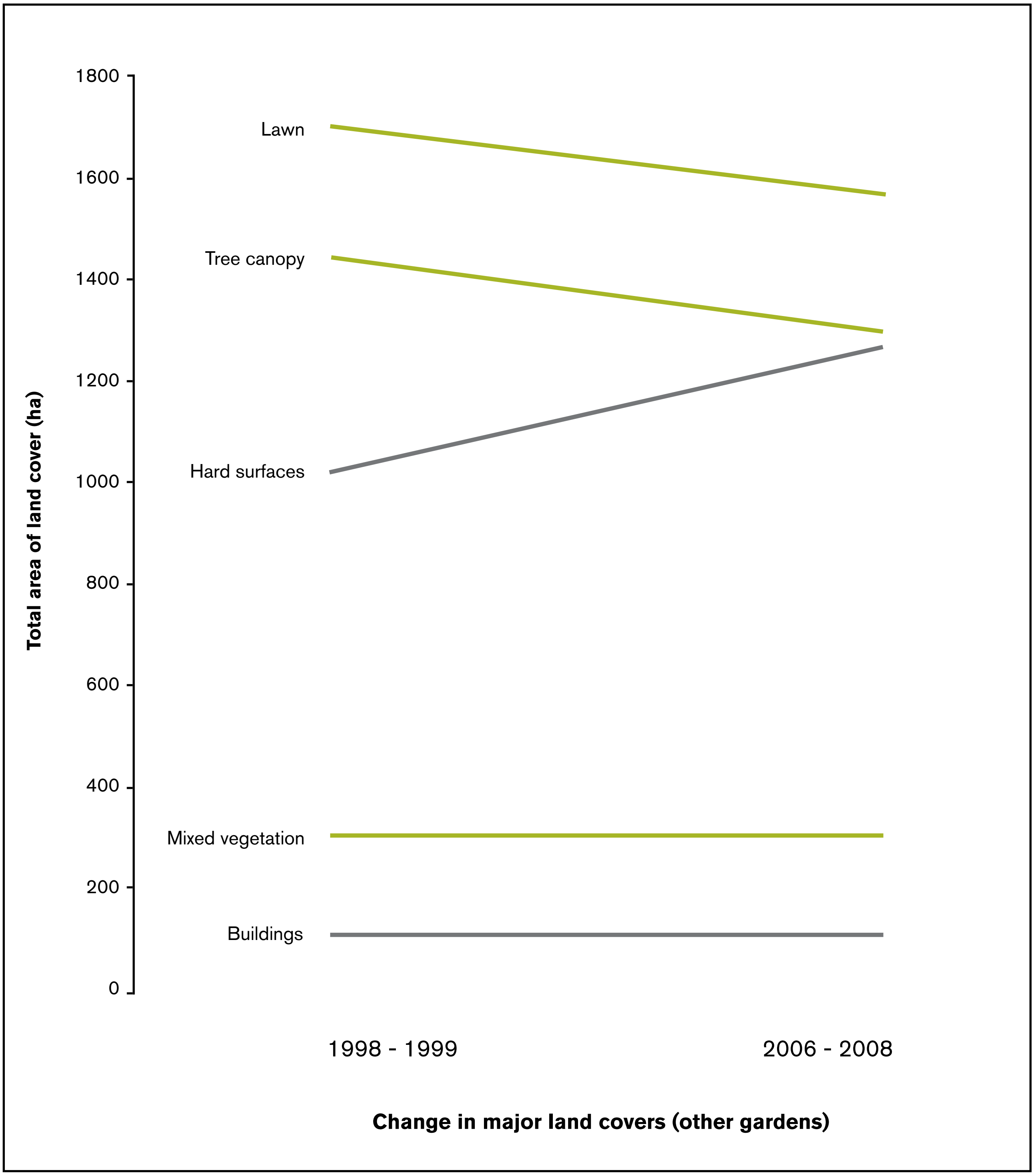



**Chart 1.5** - changes over 8.5 year study period in the total area of various land covers found in other garden plots

# Discussion

## The scale of the current resource

This study has been able to improve and advance quantitative information about London's garden resource, developing the platform for informed discussion with regards to policies and practice. The results unequivocally show that London's gardens together form a substantial land use in the capital, nearly a quarter of the city's land surface.

The total area of private garden space in the UK is often quoted to be around 400,000 ha (Gilbert, 1989; Owen, 1991) and national study has recently improved this estimate to 432,924 ha (Davies, *et al*., 2009). This means that London's 37,900 ha of garden land represents around 9% of the total UK garden resource.

Although Londoners may be surprised that their garden or gardens contribute to such a large overall area of garden land in the city, the proportion of London that is garden is not unusual in the context of studies of other UK cities. Research carried out in Sheffield found approximately 23% (33 $km^2$) of the city area comprises of domestic gardens (Gaston *et al*., 2004b) and a study comparing the garden resources in five UK cities – Edinburgh, Belfast, Leicester, Oxford and Cardiff – calculated that the area of each city covered by domestic gardens ranged from 21.8% to 26.8% (Loram *et al*., 2007).

The total area of garden in London is not contiguous; approximately 2 million dwellings, including shared flats and multiple occupancy buildings, have gardens and garden land is therefore subject to physical fragmentation as well as fragmented ownership. Each garden plot within the total garden space of London is subject to varying design, use, management and maintenance; each will have their own history. This represents a unique situation compared with other (semi-) natural habitats in the city. To understand the role of the garden resource in London, this study analysed the features within garden plots on a London-wide scale for the first time.

## Green spaces

Anecdotally, London is known to be one of the greenest - most verdant - cities in Europe. Clearly there is compelling evidence that gardens contribute to a significant green habitat in the capital. Over half of the garden land in London includes vegetation cover – including grassy lawns, flower beds and low level vegetation, hedges and tree canopy. Taken together, this total area of vegetated land cover in London's gardens is estimated to be 22,000 ha (over 150 times the size of Hyde Park) approximately 14% of London. For comparison, the vegetated areas of London's garden plots amount to almost 75% of the combined area of London's Sites of Importance for Nature Conservation, which number about 1500 in total).

Habitats within a typical private garden can be home to a diverse range of wildlife. More than 700 invertebrate species were identified within a sample of gardens in Sheffield (Gaston *et al*., 2004). Jennifer Owen found 91 hoverfly, 343 moth, 21 butterfly, 51 bee, 41 wasp and 251 beetle species in a long-term study of her Leicestershire garden (Owen, 1991). Good invertebrate diversity encourages a range of other species. The Mammal Society found 43 different mammal species in gardens, with an average of five mammals observed in a single garden (Harris, 2002). Birds are well known garden visitors, and manage to maintain high population densities in areas of human settlement thanks to garden habitats. In an analysis of Breeding Bird Survey data, Newson *et al*. (2005) found a large proportion (17-62%) of the populations of common bird species (blackbird, song thrush, dunnock, greenfinch, starling, house sparrow, wood pigeon and jackdaw) were found in locations containing habitat associated with humans, though 10% of the UK was estimated to be classified as such habitat. The range of vegetation that was identified in this study indicates that many of London's gardens may have suitable habitat for a range of wildlife.

There is a fairly large area of tree canopy within London's gardens, 6,700 ha in total (47 times the area of Hyde Park), which represents 4% of London. Some of this canopy cover will be due to over-hang of non-garden trees, e.g. street trees. This strategy estimates that there are around 2.5 million mature trees actually growing within London's garden plots, which will account for most of the canopy area. London's garden trees are likely to represent an important habitat resource for tree-dwelling species in gardens. However, there may be in the region of seven million trees in Greater London, about a quarter of which are in woodland (Dawson, 2005). Trees provide about 18% cover in gardens compared with an estimate of 30% for London as a whole (Dawson, 2005).

Garden trees are likely to increase the biodiversity of individual gardens, for example garden trees were one of the most important correlates with insect diversity in gardens in Sheffield (Smith *et al*., 2006). The protection of the garden tree resource must be an important aim. However, trees can be controversial in residential areas. They may cause problems with regards to roots, shade, leaf and fruit fall and require some maintenance. A few tree species may cause additional structural problems through suckering (e.g. *Ailanthus* and *Robinia*). Developing positive attitudes to garden trees may be a good mechanism to promote the protection of existing trees and the planting of more (for example, as in the Forestry Commission's Tree and Woodland Framework for London *http://www.forestry.gov.uk/ltwf*). There is hope that some people are already doing this, given that the decline of garden tree canopy cover over the last eight and a half years has generally been less than that of lawn or other kinds of vegetation.

Lawns are a popular and practical land cover in traditional British gardens (a direct descendent of 18th century English landscape design) and this is reflected in the garden space of London. Nearly a third of London's garden space is covered by lawn. Lawns occupy a much larger area of London's garden resource than other forms of garden vegetation, mainly due to their cover in back gardens, and are therefore important to consider in approaches to preserving and improving the garden green space. Lawns may also play a critical role in the development of sustainable drainage systems and in the building of soils, which are often depleted in urban areas (Gaston *et al*., 2005b).

Studies have shown that a normal garden lawn can be surprisingly biodiverse, although this is dependent on the underlying substrates, age and management. Thompson *et al*. (2004) measured the floral composition and diversity of lawns in Sheffield. They found a wide diversity of plants growing in lawns (159 vascular plant species were identified). In particular, lawns were an important source of native plant species within gardens, accounting for up to 69% of the total native richness of the gardens in Sheffield.

The value of lawns for wildlife is likely to be strongly dependent on management techniques. The species in a garden lawn will depend on various factors, including the lawn age, height and frequency of cutting, soil fertility, use of herbicides and initial seed mixture (Gilbert, 1989). Garden owners may be surprised by lawns' special ability to maintain native species and so to boost the biodiversity of a typical garden. This presents an opportunity to emphasise the importance of relaxing lawn management techniques to enhance their wildlife role, and the benefits of lawns over hard surfaces as a ground cover.

Other kinds of vegetation including hedges, climbers, shrubs and herbaceous borders were less extensive in their area coverage of London's gardens than lawn or tree canopy. These habitats and features are most difficult to identify with the methods employed, and may therefore be slightly underestimated. Following Owen's idea of a garden representing a habitat in a permanent state of succession (Owen, 1991), this mixed vegetation may be seen as a garden's 'woodland edge flora'. It is therefore an important intermediate habitat for many garden species, forming edge habitats and various sources of shelter and food.

Garden borders may be particularly important sources of soil biodiversity. Smith *et al*. (2006) sampled lawn and border soil invertebrate diversity in public parks and gardens in the borough of Kensington and Chelsea, London. They demonstrated that garden planted borders can be a good source of native soil biodiversity in urban areas, and suggested that the environmental heterogeneity and low level of disturbance of borders favour a higher invertebrate diversity than is found in typically more homogeneous lawns. The study focused on invertebrate diversity, but soil diversity also benefits plant communities and other species such as birds and small mammals that feed on invertebrates. Though they cover a smaller area of gardens, hedgerows, climbers and planted borders can be important for supporting wildlife in gardens.

Altogether, the sheer scale of the green space resource in gardens suggests that the vegetated area of gardens within the capital is a significant and strategically important wildlife habitat. However, because of the fragmented nature and management of private garden and the transient nature of garden ownership and lack of protective status, the quality of habitats across the whole resource is likely to be very variable. Changes to the management of a large enough proportion of gardens in London clearly has the potential to benefit wildlife conservation significantly.

### Variation within London's gardens

Two of the key sources of variation within London's gardens were garden plot size and/or type. The typical front garden plot is different from the typical back or 'other' types of garden in terms of land cover composition, and smaller plots were also likely to have different coverage compared to larger plots. The two factors are also linked, because front gardens tend to be small. We didn't test here the inter-category correlation.

Nationally the average area of garden associated with a dwelling (i.e. front plus back where both are present) is estimated to be around 190m$^2$ (Davies *et al*., 2009). This study has found the equivalent area of garden in London to be 200m$^2$. In Edinburgh, Belfast, Leicester, Oxford and Cardiff mean garden areas by this definition range from 155 to 253m$^2$ (Loram *et al*., 2007), so London gardens appear no different in size to those in other UK cities.

Urban gardens tend to have strongly skewed size distributions (Gaston *et al*., 2005b; Loram et al., 2007), meaning there is a large number of small gardens compared to relatively few larger gardens. This is also the case for London's garden plots, meaning that small plots are very common.

There were marked differences between different types of garden plot in London. Front plots tend to have a larger area of hard surface and less area given over to vegetation, whereas back and other kinds of garden plot are most important for providing vegetated habitats and usually have less hard surfacing. One of the main reasons for these differences is likely to be their sizes. Garden plot size was correlated with garden type: front garden plots are smallest (mean $56m^2$), back garden plots are much larger (mean $150m^2$) and other types of plot are largest (mean $170m^2$). As outlined above, the size of a garden is an important factor in determining its composition. However, there are of course also social and functional differences between different types of garden plot that will affect composition.

Independent of garden plot type, there was a greater variety of habitat types to be found in large garden plots than in small ones. It seems likely that a block including numerous large garden plots will have a greater diversity of habitat than a similarly large block mosly comprising of small garden plots. In summary, size and type of a garden are likely to be key considerations driving the composition of individual gardens and therefore are also an important source of variation to take into account when engaging the public with garden issues.

### Small gardens

A large number of small garden plots in a city present certain challenges for garden wildlife. The findings for London support those of Smith *et al*. (2005) that garden size plays a significant role in determining the resources for wildlife they may contain. Many London garden plots are small, and this small size has an impact on internal composition, probably because of the physical and perceived limitations that small size imposes upon garden design and management.

One characteristic of small garden plots is that the proportional cover of certain features decline with garden area. In London's gardens the proportional cover of hedges, climbers, flower beds and shrubs declined with increasing garden plot size. Smith *et al*. (2005) also found that the proportional cover of their land cover category 'cultivated flower bed' was negatively related to garden area. In both cases this relationship occurs because as gardens become smaller the ratio of perimeter to area increases. So in small gardens, planting that is around the perimeter boundary, such as a flower bed or hedgerow, will occupy a larger proportion of the garden area than the same feature in a large garden. The planting of hedges, border vegetation and climbers along fences may therefore be particularly important for small gardens to improve habitat availability, and presents a practical way of introducing vegetation for small gardens where space is at a premium. The cumulative habitat of perimeter vegetation in many small gardens where they form a block of gardens may also benefit some species.

It was also found that features which tend to be a fixed size such as hard surfacing, buildings and side passageways occupy a larger proportion of small garden plots than large plots. For example, a 5 x 5m patio will cover a larger proportion of a $50m^2$ garden plot than a $150m^2$ plot. Smith *et al.* (2005) found a similar relationship between equivalent land cover categories and garden size for back garden plots in Sheffield.

This has important consequences regarding advice for smaller gardens. The issue of hard surfacing may be most important for smaller gardens, where this is likely to be a dominant land cover (not only in the individual garden, but accumulatively within a mosaic of small gardens). Novel approaches to hard surfacing, which reduce the effective size of standard patios or paths may be particularly important for small gardens to reduce the overall proportional cover of hard surfacing and improve drainage.

There was a considerable difference in the average sized garden between different London boroughs, mostly reflecting their different levels of urbanisation and historic development. Outer-London boroughs such as Bromley and Barnet, which are characteristically suburban and with much detached (and semi-detached) housing, included garden plots with the largest average sizes, whereas, inner London boroughs, which are more densely populated, or much terraced housing or flats such as Kensington and Chelsea and City of Westminster, had typically small garden plots.

This finding has potential consequences for the approach to garden advice for different boroughs. 'Small garden advice' focusing on greening up hard surface and introducing more habitat diversity would be best focused on certain (especially inner London) boroughs. 'Larger garden advice', highlighting the importance of wildlife-friendly lawn management, pond construction and the retention of trees may be best targeted at boroughs at the top end of the scale of average garden size where back gardens, in particular, will include areas distant from the dwelling.

### Front gardens

Together, front garden plots make up a smaller proportion of London's garden space (25%) than back gardens (63%). Nevertheless, the total front garden resource is large and, as rows of adjacent front gardens are a commonly seen in London, the habitats within front gardens could have a significant local landscape effect too. The overall area of front garden plots estimated in this study is also two times greater than the "conservative estimate" of 47.8 $km^2$ (4780 ha) of front garden space in London used by the Greater London Assembly Environment Committee's *Crazy Paving* study (Greater London Assembly Environment Committee, 2005). In addition, front garden plots contribute disproportionately to the overall amount of hard surfacing in London. It is calculated here that London's front garden plots contribute 5900 ha of hard surfacing, 41 times the size of Hyde Park (a figure much greater than a previous estimate in a smaller scale study of 3200 ha (Greater London Assembly Environment Committee, 2005)). The issues surrounding hard surfacing are therefore particularly significant in front gardens.

The composition of London's front gardens is likely to reflect their function as well as typically small size. Hard surfacing appears to be an important land cover in all types of garden plot, but it is the major land cover in front garden plots. Front gardens normally lead onto a public highway and are more open and visible than back gardens. They are therefore more appropriate as a parking space for vehicles, likely to have access to the front door via a hard surface path and are perhaps less likely to be used for leisure activities. Front plots are also much more likely to function as a display of status as they are most publicly visible. The composition of an average London garden suggests that these roles are important to front garden owners.

Hard surfacing of gardens for practical reasons may occur at the expense of vegetation, therefore reducing habitat availability for wildlife. Smith *et al*., (2005) found that land cover types that tend to remain at a constant absolute size may be present at the expense of vegetated land cover in smaller back gardens. Evidence from London's garden plots suggests that this relationship may be even more important for front gardens. Front garden plots tended to have a larger proportion of space given over to fewer land cover types, with hard surfaces dominating, at the expense of vegetated habitats.

Hard surfacing that is impermeable causes the additional problem of reducing rain water drainage and causing run-off of water and flooding problems (Communities and Local Government, 2008). Hard surfaces also have a higher maximum daytime surface temperature (Communities and Local Government, 2008). The extensive hard surface cover coupled with a parallel lack of vegetation in front gardens means that the hard surfaced areas in these gardens are also less likely to be 'buffered' by softer land covers either within the garden or in adjoining gardens than is the case for hard surfaced areas in back or other gardens. Drainage problems are therefore likely to be more significant for front gardens than backs, compounding the impact that this will have upon adjoining pavements and roads.

### Back and other garden types

Back gardens comprise 63% of the total garden land area in London. This means that how people chose to use and manage their back garden plot has an important influence on the total area of London's garden habitat. The average composition of a back garden in London perhaps reflects the traditional British garden design: a large area of lawn and an area of hard surfacing (patio and path), smaller areas of planting (herbaceous plants and shrubs), a tree and at least one outbuilding (shed, glasshouse etc.). In general a back garden plot in London has a more equitable cover of different land cover types than front gardens, which tend to be dominated by hard surface. A mixture of different surfaces and habitats means that back gardens are a richer source of habitat diversity for wildlife than front gardens.

Back gardens are also typically larger, which means that they may be more likely to have undisturbed areas at some distance from the dwelling with benefits for wildlife in terms of habitat disturbance and breeding. This is unlike the situation in front gardens, which are by definition more likely to be near to roads and more frequently disturbed by passers-by and foot access to the dwelling.

Back gardens tend to be largely covered by vegetated habitats. On average, 64% of a London back garden was 'green habitats', compared with only 35% of the average front garden. Back garden plots are particularly important for garden trees. About 1.9 million of the 2.5 million trees in London's garden plots are found in back plots, which is an average of about 1 tree per back plot (one tree was also present, on average, in every 'other' garden, though being rarer, these gardens contributed less to the total number of garden trees – 270,000 trees). This compares with only 400,000 trees found in front garden plots (an average of about one tree in every five front plots).

Back and 'other' garden plots are very similar in their composition, with lawn occupying the biggest area of space. Buildings are more likely to be found in back gardens, which reflects the available space as well as the privacy of the back garden space compared to the typically overlooked front or 'other' garden (which may also typically be communal).

Based on national information, it has been suggested that larger gardens provide the best habitat for mammals, including hedgehog *(Erinaceus europaeus)*, fox *(Vulpes vulpes)*, grey squirrel *(Sciurus carolinensis)*, wood mouse *(Apodemus sylvaticus)*, occasionally common shrew *(Sorex araneus)* and, when they are well vegetated, the bank vole *(Clethrionomys glareolus)* (Gilbert, 1989; Harris, 2002). Back and 'other' kinds of garden plot in London are considerably larger than front garden plots and have more variety of habitats. They may therefore be much more likely to be able to provide the habitat suitable for mammals and this could be a particular focus in some of the outer boroughs. Where plots together form blocks of garden, these are more likely to be large plot and to include a wide range of habitats than a similar number of smaller front gardens.

### Change in gardens

By examining measurable changes in land cover between garden plots that could be seen in both early and recent photographs, this study was able to estimate the overall changes that have occurred to the London garden resource due to gardening trends and uses. We were unable to study the loss or gain of whole gardens in any detail.

Garden hard surfaces in general have increased in area by 26% over the study period, which is a gain of twice the area of Hyde Park every year. When correctly laid, most modern paving materials shed water off their surface, resulting in excess water running away into sewers and drains rather than soaking into the land (Anon, 2006). The permeability of the hard surfacing recorded in this study is unknown because of the aerial photograph interpretation methods employed. However, it is likely that much of the hard surfacing recorded in front gardens is impermeable. Traditional impermeable driveways that allow uncontrolled runoff of rainwater from front gardens onto roads can contribute to flooding and pollution of watercourses (Communities and Local Government, 2008). Increased levels of rainwater run-off from hard surfaces in London increase the water flow into combined outflow drainage systems. This means that, in times of heavy rainfall, there is a greater likelihood of sewage discharge into London's rivers and the possibility of localised flooding (GLA, 2005). The large increase in garden hard surfaces over the study period means that the permeability of London's garden area has also likely decreased considerably during this time.

Aside from the rate of garden vegetation loss, the changes in all green habitats detected in this study represent a real loss of wildlife habitat during this period. A mean of 6m$^2$ of vegetation has been lost in an average front garden plot and 11m$^2$ of vegetation lost in a back garden plot over 8.5 years. The loss of each tree, hedge or square metre of lawn is a loss for the wildlife that depends upon these habitats. On an individual garden plot scale, changes in composition of garden land covers can have significant impact on the biodiversity value of a garden. On the scale of a block of suburban garden plots, changes occurring somewhere in the block will adversely affect the variety of wildlife to be seen in any one of the component gardens (Dawson & Gittings, 1990).

These changes also have to be considered with regards to our changing climate. Buildings and hard surfaces in an urban environment absorb solar radiation, causing an increase in air temperature within urban centres above that of surrounding areas – the 'urban heat island effect'. Vegetated spaces within an urban matrix of land covers have the opposite effect, because evapotranspiration from vegetation and soils leads to a cooling of air temperatures (Taha *et al*., 2000). Where gardens include a vegetated component of land cover they are likely to be contributing to this cooling effect in built up areas. The London Climate Change Adaptation Strategy outlines climate projections taken from the Hadley Centre's Regional Climate Modeling for the UK and south-east England (and therefore Greater London). All climate change scenarios predict warmer, wetter winters, hotter, drier summers and an increase in the frequency and intensity of extreme weather in Greater London (GLA, 2008). Therefore, with rising temperatures the green spaces in London's gardens may be more important than ever before to adapt to the impacts of climate change. The loss of vegetated land cover from London's gardens is therefore a concern and a trend that needs to be reversed if the full potential of gardens to aid climate change adaptation and comfort is to be realised. Emphasising these, perhaps hidden, environmental roles of gardens to the public and providing advice on suitable planting for increased temperatures and flooding scenarios may help to reverse this trend.

Since October 2008 the paving of front gardens for hard standing is no longer a permitted development right without planning permission. It is permitted to lay new (or replacement) driveways or parking areas greater than 5m$^2$ only if they are constructed using permeable surfaces that allow water to soak into the ground, for example porous asphalt or gravel (Communities and Local Government, 2008). This legislation may slow the trend of increased hard surfacing of London's gardens in the future, or at least improve the permeability of the hard surfacing that is being used. However, it remains to be seen how strictly enforced this legislation will be and how many planning applications will be made and accepted for the impermeable hard surfacing of gardens. Emphasis of this new legislation and, in particular, encouragement to convert impermeable hard surfacing to permeable alternatives, should be key public engagement strategies to reduce the environmental impact of garden hard surfaces. Importantly, this legislation does not mitigate for the loss of vegetated land covers that is the parallel trend with increasing hard surfacing found in this study.

Garden buildings (as measureable in this study) have increased in area from 1,800 ha to 2,800 ha. The increase in garden buildings is a particular phenomenon of back gardens, 94% of the increase in buildings occurred in back gardens. The magnitude of this trend was unexpected and suggests that garden sheds and glasshouses are a more common feature, though the use of these buildings is not known, as the category was not further divided in this study. This category will have included some, but not all, extensions to houses added during the study period, which is a limitation to interpretation. However, it is clear that a trend towards increased area of buildings in gardens exists and is apparently at the expense of back garden vegetated habitat, which is a cause for concern. The contribution of building extensions to this trend and the nature of outbuildings involved is a priority for future enquiry. Encouraging climbers on fences and the walls of buildings and the construction of green roofs could partly mitigate for the loss of vegetation to garden buildings.

Significantly, the increase in hard surfaces and buildings in London's gardens has been a driver of major losses of green habitat in the capital. In front garden plots a loss of vegetation has been largely due to its replacement with hard surfaces – likely to be the paving over of front gardens for car parking and convenience. In back garden plots, vegetation has been lost almost equally to hard surfaces and the construction or extension of buildings.

In total, an area of vegetated garden land about 21 times the size of Hyde Park was lost over the 8.5 years studied, representing a 12% reduction on the amount in 1998-99. Yearly this represents a loss of an area two and a half times the size of Hyde Park, which is a cause for concern, should this trend continue. Hypothetically, if the loss of green space observed during the period of study were to carry on, we would lose all of our garden green space by the year 2068. This is unlikely to happen for a number of reasons, but it emphasises a worrying trend.

The loss of lawn habitat in particular is a statistically significant change. We can be certain this loss is not a result of chance in the sample. The loss of other vegetation also showed a downward trend, but this could be the result of chance, so studies across further years would be necessary to find out if this is a real long term trend, as might be expected. Perhaps surprisingly, the number of trees growing in gardens changed little over the study period, with just the hint of a small loss. This suggests that the removal of garden trees is less of a concern than might be anticipated across the whole of London over this time scale. A longer-term study would be required to see if there is a significant decline over a greater time period.

It is very possible that a considerable amount of loss of green space, particularly due to the paving over of front gardens for parking, may have occurred prior to the time period of study, as the drivers of this loss clearly pre-date the study period in origin. Unfortunately, the quality of earlier aerial photographs available was not good enough to allow examination of earlier change. Without a longer term study it is hard to know whether the trend might begin to slow, however, it is clear that it must be a goal of conservation organisations to slow or reverse this trend now.

## Conclusions

In terms of the direct loss of wildlife habitats, increased rainwater runoff and raised daytime surface temperatures, the trend of the replacement of vegetation for hard surfacing and buildings is a major concern. These issues become more concerning in a future climate scenario of increased daytime temperatures and reduced rainfall. Urban green spaces can represent a wildlife resource that is not subject to the factors leading to loss or degradation of habitats in rural areas (e.g. agriculture), with the additional benefits of providing people with a direct contact with the natural world. However, evidence suggests that current trends in the loss of total garden vegetation are harming our garden resource both for wildlife and as mitigation for the likely effects of climate change.

If we are to maximise the potential of London's gardens to support biodiversity, the trend of increased hard surfacing and reduced vegetation in them needs to be halted and reversed. But a limitation of gardens as a conservation resource is that they are outside the immediate control of local government and other agencies (Gaston *et al*., 2005a); this makes it difficult to directly influence management.

A key mechanism for change is therefore engaging public involvement. Key aims for public engagement must be: firstly, to highlight the significant role of individual garden habitats in terms of contributing to the overall garden resource and, secondly, to drive improvements in the quality of this resource by appealing to people's interests in maintaining wildlife-friendly gardens. Voluntary nature conservation organisations, such as London Wildlife Trust, have an important role to engage with members of the public and influence wildlife- and climate-friendly management of gardens. For example, the Trust launched its 'Garden for a Living London' campaign in July 2008 to raise awareness of the value of London's gardens and ask Londoners to do one thing to create a wildlife and climate change friendly garden. This campaign will benefit from the improved baseline information generated in the present study.

To a garden owner, the area of their individual garden may seem limited, particularly for those living in inner city terraced housing, but the sum of all these gardens contributes substantially to the overall amount of green space in urban areas across the country (Davies *et al*., 2009). The findings of this project document how individual gardens in London contribute to a strategically important green space resource. This information can be used to highlight the importance of the combined garden resource in London and motivate individual garden owners to protect or improve the quality of their garden as part of a broader neighbourhood green space.

The size of garden plots and plot type appear to be influential (related) factors of in terms of the composition of London gardens, and the changes to land covers that occurred were different in front, back and other kinds of garden plot (though further work is needed to see how the two factors relate to each other). This strongly suggests that advice regarding wildlife friendly garden design and management would be most efficient if tailored to certain types and sizes of garden, as well as different kinds of people. The large number of small garden plots, particularly in some parts of London, means that advice for people should be specifically tailored to address the issues of small gardens.

Aside from public engagement, the second mechanism for change is legislation, regulation and policy, with effective enforcement mechanisms. There is now a requirement for planning permission to be received in order to pave more than five square metres of a front garden with traditional, impermeable driveways that do not provide for the water to run to a permeable area (Communities and Local Government, 2008). This is an improvement on previous situation by raising awareness of the drainage consequences of hard surfacing garden land and encouraging good practice. It may deter some cases of unnecessary paving altogether. However the paving legislation does not concern the loss of vegetation (or consequences for wildlife habitat or cooling effects) that can occur regardless of surface type and success depends on adequate enforcement.

Existing planning controls are in place to prevent inappropriate housing development on back garden land. In particular the declassification of gardens as previously developed land or 'brownfield' in summer 2010 (Communities and Local Government, 2010b) has gone some way to changing how they are perceived by developers and relieves gardens from inclusion in local authority targets for previously developed land. The effects of housing development are dealt with in **study 2** of this report.

The findings here highlight not only the value of London's garden land for wildlife habitat and as an environmental resource, but also show that these roles are under threat. This report therefore provides evidence to support future policy decisions.

# Study 2: Gardens subject to housing development

## Introduction

The loss of front garden vegetated land to paving for parking areas and the loss of back garden land to in-fill housing developments can be seen as the two main concerns regarding changes to garden green space over time. This part of the Garden Research Project addresses the latter issue, with the aim of quantifying the impact that known housing developments have on the land cover in gardens.

The Greater London Authority (GLA) has highlighted the importance of gardens as a green space within London and in particular, has drawn attention to housing development on back gardens (often dubbed 'garden grabbing', 'in-fill', or 'backland development') as a key issue. Most new buildings or major changes to existing buildings need planning permission (see *www.planningportal.gov.uk*). The GLA maintain the London Development Database (LDD), which includes records of planning permissions meeting specific criteria from Greater London.

Until recently gardens were designated as 'previously developed land', commonly termed brownfield land in planning guidance. On June 9th 2010, gardens were removed from the brownfield classification in Planning Policy Statement 3 (PPS3) on Housing, the intended effect that gardens do not come under pressure from previously developed land targets and trajectories for strategic housing development plans (Communities and Local Government, 2010b). This does not mean that garden land is under no pressure at all from development, but gives local authorities more freedom to judge individual applications on local appropriateness and makes appeal on grounds of affordable housing needs less likely (Communities and Local Government, 2010a).

This study aims to qualify the impacts of developments where they have been completed to understand the changes that occur to that land as a consequence.

Determining if there has been change in numbers of developments or impacts over time was not the intention of this report, though this has been done elsewhere by different methodology (see Communities and Local Government, 2010a).

## Methods

### Developments that were investigated

The London Development Database includes details of both 'live' and 'completed' developments given planning permission. The database was filtered to identify housing developments, completed between 1st April 2005 and 31st March 2008, which were probably carried out on garden land according to details available. These were developments where the previous and final land use was given as 'residential' and there were no housing units on the site before development, to exclude estate redevelopments. Developments ranged from single terraced houses built onto the end of a row of houses, to small developments of several properties on a number of gardens. These developments were examined with the aim of estimating the changes that occurred to the garden surfaces subject to development. There are many smaller developments and minor changes to existing buildings that can be carried out on garden land without planning permission, and these 'permitted developments' are not examined in this study (although they are clearly likely to have an impact, as suggested in **Study 1**).

### Geographical Information System

A Geographic Information System (GIS) was built in MapInfo Professional 9.5 to include topographical information about London and information about selected developments. In total, 1115 sites were identified in the LDD (financial years 2005-07) as developments that may affect private garden land. The co-ordinates of these developments were displayed as points (eastings and northings) in the GIS. This GIS included: a) polygons defining garden land from MasterMap®, an Ordnance Survey database of topographical information and b) Ordnance Survey street and house names, c) two series of aerial photographs of Greater London, the first taken in 1998-99 and the second in 2006-08 (Cities Revealed).

Aerial photographs enable known larger developments on garden land to be observed both before and after development is complete. This has the advantage of allowing us to see the changes that have occurred to garden plots directly because of housing development during the time period available for study.

### Systematic assessment

Each suspected garden development was first assessed visually in a two stage systematic checking process:
*Stage 1*: Developments were inspected to check if they affected private garden land, as defined by MasterMap®. Those that did not involve garden land were disregarded. Sites where the housing development and/or final landscaping within the development curtilage was not complete were also not analysed further.
*Stage 2*: Development sites were assessed for quality of visual information. Sites were disregarded when it was estimated that visual information was obscured for more than 20% of the area being assessed. Three criteria were considered: i) poor photograph exposure or blur, ii) non-vertical photograph angle, iii) deep shadow over an area.

### Land cover assessment

Following the checks described above, the curtilage boundary of a development was estimated and digitised on-screen. Curtilage boundary was defined as the boundary of the new development, including the building, garden and driveway/parking space. This was taken either from the current OS MasterMap® boundary, where this had been updated to reflect the new development, or a visual estimate from the aerial photograph.

The proportions of habitats, surfaces and unknown areas within the defined curtilage boundary were then estimated (to nearest 5% cover) both in the pre-development and post-development photographs. The number of mature trees (judged as a crown canopy of >2m wide) assessed as growing within the curtilage boundary was estimated. The number of garden plots intersecting the development curtilage was recorded before and after development occurred as in some cases more than one garden plot is involved in a development. It is important to note that the garden habitats recorded in the 'before development' data do not necessarily represent a whole garden plot, but the area that is within the curtilage of the planned development. This area may therefore include parts of one or several garden plots, and in a very few cases, also an area that is not garden land.

Land cover categories recorded were the same as those used for the study of garden change in chapter one. The only exception was that in this study of development 'building' refers to newly built dwelling houses as well as garden buildings such as sheds and glass houses (**table 2.1**). Because the curtilage boundary was defined by the recorder, land cover estimates were not affected if the new garden and dwelling boundaries had been updated in the MasterMap® layer The categories were defined by appraising photograph quality and ground truth survey of volunteers' gardens. This process is outlined in **appendix 1.2** of chapter one.

| Land cover type | Definition |
|---|---|
| Tree canopy | A 'tree' refers to a mature woody species (or with a 2m wide canopy). No further distinction (e.g. between coniferous or deciduous) was made. |
| "Other vegetation" | Includes, small to medium sized (<2m wide) herbaceous or woody plants – flowers, shrubs etc. such as grown typically in a flower bed – scrub growth such as bramble cover, climbers such as ivy or wisteria and hedges. |
| Lawn | A grass/turf area. May be densely or sparsely vegetated, tall or closely mown. In this study lawn, also includes areas dominated by small ephemeral herbaceous plants. |
| Hard surfacing | Includes full spectrum of permeability e.g. paving, bricks, concrete, gravel or 'decking'. Includes patios, paths, steps and driveways. |
| Building | All sheds, glasshouses, summerhouses and other small (<12m$^2$) detached buildings, house extensions completed after June 2006 and some (unknown proportion of) extensions prior to this date (see appendix 1.3). |
| Side passageway | Narrow side path or passage along the side or between houses that is included within the garden polygon. Often shaded, but likely to be hard surface. |
| Other | Land cover type that is recognisable (i.e. not 'unknown') but doesn't fit into any of the broader categories. Typically, swimming pools, large compost heaps, garden debris, garden furniture and occasional large ponds. |
| Unknown | Area of garden that is obscured by deep shadow, poor photograph exposure or due to the photograph angle. |

**Table 2.1** – Land cover categories and definitions

### The Sample

On visual examination of the suggested sites from the LDD, 934 records were accepted to be developments that were given permission upon private garden land (181 developments did not affect gardens). There were 319 developments in financial year (FY) 2005-06, 314 developments in FY 2006-07 and 301 developments in FY 2007-08 on garden land. Of these developments, 172 (54%) in FY 2005-06, 161 (51%) in FY 2006-07 and 78 (26%) in FY 2007-08 (total 411) were completed at the time of the aerial photograph and acceptable on grounds of photograph quality.

The most recent set of aerial photographs used for analysis were taken between 2006 and 2008, with most dating from 2006-07. Recent developments were more likely to be incomplete at the time of photography, which explains why the housing development completions in the LDD from 2007 were under-represented in the sample compared with those completed in 2005 and 2006.

In order to make conclusions about the impact of all developments over the three years in question, it was necessary to assume that the non-assessed developments were not significantly different from the assessed developments. The rejected and recorded garden developments were therefore assessed to see if there was any observable systematic bias – none was found (see **box 1**).

### Estimating total areas

The area of land cover types was calculated by multiplying estimated percentage cover (expressed as a decimal fraction) of a land cover type by development curtilage area (rounded to nearest m$^2$) for each individual development assessed (once for each time period). As there was no appreciable bias in terms of development size (see **box 1**) within the sample, it was possible to scale up estimates to the total area of housing developments across the three years to give us the best estimates of the total amounts of various land covers affected by back garden developments between 1st April 2005 and 31st March 2008.

**Box 1**

Checks were performed to test if there was a difference in curtilage size between: a) developments that were analysed and those that did not pass initial checks; and b) developments from sites that were accepted for analysis in different years.

Development size was judged from the 'residential site area' in the LDD. An outlier and null entries were first removed.

A Wilcoxon signed rank test with continuity correction (Wilcoxon Mann-Whitney) found no significant difference in the residential site area between accepted and rejected developments, as indicated by median site areas (0.024 ha and 0.022 ha, respectively).

A Kruskal-Wallis rank sum test found no significant difference between development areas in the three years (2005 median= 0.022 ha, 2006 median = 0.023 ha, 2007 median = 0.025 ha).

The findings of these checks show that the rejection of some developments did not bias the average site size, so there is no evidence that the assessment process biased the sample available for analysis.

This was done year by year, to account for the smaller sample from 2007 and because there is interest in per annum totals. The average (arithmetic mean) area of each land cover per development in the sample was calculated (total area/number of developments in sample) within each year. This average was then multiplied by the total number of developments (i.e. all completed developments on garden land) in each year to get the area of habitat and the year totals were summed to find the overall total area in the three financial years. Areas were calculated separately for the time period before development and after development, so that change could be estimated. A similar method was used to calculate the number of trees present and gardens impacted, before and after development.

The total area of unknown garden land cover (scaled up to all developments) was 4.6 ha before development and 2.6 ha after development. As a best estimate from the available information, the nature of the unknown area was estimated by proportionally distributing it between the known categories of land cover.

## Results

The median size of a housing development curtilage across the three years studied was 246m$^2$; the mean size was 422 m$^2$. The distribution of development sizes was right skewed, meaning that there were many small developments and fewer large developments. At any one development site, the number of new housing units varied between 1 and 9, but 80% were single house developments (mean 1.35, median 1 new housing unit per development).

### Changes due to development

Over the three financial years studied, 934 (average of 311 per annum) housing developments from the LDD were assessed as impacting garden land. When data from the sample are scaled up it is calculated that these developments affected approximately 13 ha of garden land in FY 2005-06, 12 ha of garden land in FY 2006-07 and 15 ha of garden land in FY 2007-08, which included at least part of approximately 486, 527 and 486 garden plots in each year respectively.

Following completion, there was an average of 703 garden plots per annum within or intersecting the areas subject to developments. This represents an average increase of 203 garden plots per annum. This is because many developments involved the creation of a new house, or new houses, with associated new smaller garden plots. However, the increase in number of plots does not necessarily mean an increase in the area of garden green space or inform us about the quality of those new gardens. Therefore, a key consideration in terms of impact of housing developments is the changes that occur to the total cover of various surfaces and habitats within the new-build curtilage.

All land cover types within the area affected by development underwent a change in total area. A paired Wilcoxon signed rank test with continuity correction on raw area data in the sample confirmed that there was a significant difference between before and after areas of all land cover types (see **appendix 2**). Before development, there was proportionately more 'green' land cover (tree canopy, mixed vegetation and lawn) than 'hard' features (hard surface, side passage and building). After development, the proportion of land that was 'green' decreased, where 'hard' features increased.

There was an average loss of 6.2 ha per annum (5.4 ha in FY 2005-06, 5.7 ha in FY 2006-07, 7.6 ha in FY 2007-08) of garden green space (tree canopy, lawn and mixed vegetation), as a consequence of all completed developments (based on scaled up figures and with unknown areas proportionally distributed between known categories). This is an average loss of 200m$^2$ vegetation per development per annum. There was an average increase of 6.4 ha per annum (5.7 ha in FY 2005-06, 5.8 ha in FY 2006-07 and 7.6 ha in FY 2007-08) of 'brown space' or 'hard' landscaping, including hard surfaces, building and side passageways. This is an average gain of 210m$^2$ of 'hard' landscaping and buildings per development per annum (including 85m$^2$ per development of hard surface – patios, driveways etc.). After development, there were an estimated 500 fewer mature trees per annum than before development (a loss of 440 in FY 2005-06, 520 in FY 2006-07 and 540 in FY 2007-08).

| Land cover | Financial year | Area, ha | | Change in area, ha | Average change per annum, ha |
|---|---|---|---|---|---|
| | | Before development | After development | | |
| Tree canopy | 2005 | 3.7 | 1.6 | -2.1 | -2.7 |
| | 2006 | 3.6 | 1.2 | -2.4 | |
| | 2007 | 6.3 | 2.6 | -3.7 | |
| Lawn | 2005 | 4.8 | 2.8 | -2.0 | -2.3 |
| | 2006 | 4.9 | 2.6 | -2.2 | |
| | 2007 | 5.1 | 2.4 | -2.7 | |
| Other vegetation | 2005 | 1.8 | 0.51 | -1.3 | -1.2 |
| | 2006 | 1.7 | 0.55 | -1.1 | |
| | 2007 | 1.7 | 0.49 | -1.2 | |
| All vegetation (tree, lawn, other) | 2005 | 10 | 4.9 | -5.4 | -6.2 |
| | 2006 | 10 | 4.4 | -5.7 | |
| | 2007 | 13 | 5.4 | -7.6 | |
| Hard surface | 2005 | 1.4 | 3.7 | 2.4 | 2.7 |
| | 2006 | 1.5 | 3.9 | 2.3 | |
| | 2007 | 1.6 | 4.8 | 3.3 | |
| Building | 2005 | 0.63 | 3.8 | 3.2 | 3.6 |
| | 2006 | 0.53 | 3.9 | 3.4 | |
| | 2007 | 0.51 | 4.7 | 4.2 | |
| Side passageway | 2005 | 0 | 0.12 | 0.12 | 0.12 |
| | 2006 | 0 | 0.14 | 0.14 | |
| | 2007 | 0 | 0.1 | 0.1 | |
| All hard surfaces (hard surface, building, side passageway) | 2005 | 2 | 7.7 | 5.7 | 6.4 |
| | 2006 | 2.1 | 7.9 | 5.8 | |
| | 2007 | 2.1 | 9.7 | 7.6 | |
| Other land cover | 2005 | 0.31 | 0.017 | -0.29 | -0.14 |
| | 2006 | 0.14 | 0.027 | -0.11 | |
| | 2007 | 0.038 | 0.02 | -0.018 | |

**Table 2.2** – total areas and change in land cover (scaled to all developments and with unknown land cover distributed) for each year, to 2 s.f.

## Conclusions

There has been an average of 311 known housing developments completed upon private garden land per annum between financial years 2005-06 and 2007-08. The land subject to development is estimated to have included at least part of an average of 500 garden plots per annum, and, although these developments led to an overall gain of on average 240 garden plots per annum, the amount of garden vegetated land within the area subject to development actually decreased significantly. The creation of new gardens by these developments is countered by the fact that these new plots are far smaller in size, and cover a smaller area than that lost from the original gardens.

A loss of around 6 ha of garden green space each year and a gain of an equivalent area of 'hard' land cover is not large in the context of nearly 38 thousand hectares of garden, and over 22 thousand hectares of garden green space that are estimated to be present in London as a whole (see **study 1** of this project report) – at this rate it would take 30 years to lose 1% of London's garden green space as a result of these larger backland developments. However, on a local scale, this impact may be significant to wildlife resources and in terms of flood drainage and climate change adaptation. The average (mean) gain of 85m$^2$ per development per annum of hard surface land cover (patios, paved pathways, drives etc.), or 210m$^2$ per development per annum if buildings and side passageways (likely to be almost always hard surfaced) are included, may represent a loss of permeability in the local area. And this gain, coupled with the average loss of 200m$^2$ green habitat per development per annum, gives increased importance to surrounding 'soft' garden space for drainage.

The loss of vegetation in gardens also represents a potential loss of local habitats for wildlife. The largest loss as a consequence of development was in the amount of tree canopy, followed closely by large losses in lawn and other types of vegetation. Mature trees represent an important breeding and feeding habitat for birds, bats and invertebrates in particular and also play an important role in terms of soil stabilisation, absorption of water, air quality and shade provision. However, an average of 500 trees was removed each year as a consequence of all known developments. This means a loss of at least one tree per development (1.5 trees on average). The losses of lawn and other vegetation taken together outweighed the loss of trees. These forms of vegetation provide wildlife habitats and "soft" surfaces that enable rainwater drainage, so these losses will have adverse impacts on wildlife and hydrology.

The impact of the changes to land cover may be considerable at a local level in terms of habitat availability and climate change adaptation. Changes to land cover are likely to be irreversible or long term (e.g. the loss of a mature tree) and therefore cumulative year on year.

During the period studied gardens were considered in the previously developed land category of planning policy guidance.

Local authority definition of garden land and treatment within strategic housing strategy has been shown to be variable between authorities and regions, as is the pressure to develop (Communities and Local Government, 2010a). Gardens are now removed from the brownfield category and associated development targets (Communities and Local Government, 2010b), which should increase powers of local authorities to assess the appropriateness of garden developments and help to reduce regional variation. However, pressure for housing development land continues and may be considered greatest in the South East and London (Communities and Local Government, 2010a) so undoubtedly gardens will continue to be proposed for development.

Decision making relies on recognition of the importance of garden space as a part of the total green space resource of an urban area and of local impacts. Planning strategies which neglect the role of gardens within estimates of green space, particularly those in urban areas, undervalue the extent of the resource (Davies, *et al*., 2009).

Study 1: Garden Land Cover shows the scale of garden contribution to London's green space. Housing development impacts annually has a small impact on this in terms of vegetation lost to hard surfaces, unlike the larger impacts of design. This means that local considerations of impacts, which include a large shift towards hard surfacing, are most important. Hopefully the de-coupling of garden housing development planning from brownfield targets should help these local impacts to take precedence in the decision making process.

With a move towards local decision making in planning, it is vital that gardens are judged according to their immediate roles for residents and wildlife but also considering their value as part of a wider green space and landscape.

# Study 3: Focusing priorities

## Introduction

The *London: Garden City?* project has been able to provide information about the scale of the capital's garden resource, component habitats, and threats to the garden green space from hard surfacing of front gardens, permitted development and the construction of new housing. Public engagement is vital for protecting and enhancing London's gardens for the future and can be aided by good baseline information. An understanding of variation within and between gardens can help to focus campaign work.

Because neighbouring gardens often form blocks of similar land use, garden habitats can be considered on a landscape scale as well as at an individual garden level. The value and role of gardens across London will vary depending on garden plot density, proximity to other wildlife habitats and the needs and lifestyles of the local population. For example, gardens that densely cover an area or are in close proximity to other green spaces can be considered as large, inter-connected patches of wildlife habitat. On the other hand, the main value of gardens in residential areas that are most isolated from other green spaces may be social, providing important contact with nature in an area that is otherwise deficient. Such areas may be overlooked by work that focuses on areas with large, habitat rich, blocks of garden or that relies on already interested gardeners. It is of interest to identify areas in London where gardens may be most important to wildlife and people, as well as areas where gardens are scarce. Awareness of local issues can help identify priority population areas for particular initiatives, garden campaigning or habitat creation.

This study examines how available data sets can answer useful questions to guide public engagement and focus priorities geographically.

## Methods

Greenspace Information for Greater London manage a wealth of data about green space and biodiversity in London, including habitat survey data, information about protected sites for nature conservation, social data and climate information. A weighted Geographical Information System (GIS) model was therefore designed to include data of particular interest. This included garden topography, areas of quality wildlife habitat, climate change modelling (heat indices), areas of deficiency in access to nature and other socio-economic information.

The model was constructed in MapInfo Professional. 9.5. This program allows different types of information to be displayed and compared on the same map. Mapable information from different sources or about different topics can be visualised in a GIS model as 'layers' of overlapping data on a base map of London. Relationships between these layers of data and topographical information can also be visualised. The layers that were included in the models are given in the **table 3.1**.

The Lower Super Output Area (LSOA) layer was used as the basic unit to divide London and assess variation in other topographical layers. This base layer was chosen because each unit division is population based, representing on average 1500 people. This allows areas with similar sized population to be compared regarding their garden resource. Focusing on units of population in this way is appropriate for the purpose of the GIS to guide public engagement with gardening for wildlife. Many other social data are also based upon this unit, which makes interpretation simpler and future developments more flexible.

The statistics within each LSOA were calculated – for example, the number of garden polygons, area of garden land, Index of Multiple Deprivation (IMD) score, area of Sites of Importance for Nature Conservation (SINCs) etc. Within each model, different factors are then differently weighted according to questions about gardens and their roles. So for example, in a model to highlight areas where gardens may have most social value, social factors such as IMD would be weighted more highly than wildlife factors.

Four functional models were created to address different questions (named map 1, 2, 3 and 4) by the different inclusion and weighting of data layers. The map concepts are outlined on pages 34-35.

| GIS map layer | Source | Information this layer provides |
|---|---|---|
| **Garden polygons** | Ordnance Survey MasterMap®. Derived from this source in June 2006. Polygons measuring <1m² were assumed to be errors and removed. | A topographical layer showing the boundary of every garden in London. Includes area and borough location information for each garden.<br><br>**Note:** The polygons in this layer include some fronts, some backs and some joint front plus back gardens (see chapter one). This means that an 'average' sized garden calculation is not accurate because it includes mixed types of polygon. However, as a rough gauge of garden size within an LSOA, a function of total garden area divided by total number of garden polygons is the best available proxy estimate at this time. |
| **Lower Super Output Areas (LSOAs)** | The Office for National Statistics and Ordnance Survey | Topographical areas of different sizes, defined as an area that includes a population of minimum 1000 people, mean 1500 people. Each area has an Index of Multiple Deprivation score, which indicates the socio-economic status of the people who live in that area. Higher scores indicate a higher level of multiple deprivation. |
| **Borough boundaries** | Ordnance Survey | Provide the administrative boundary of each of the 33 London boroughs |
| **Sites of Importance for Nature Conservation (SINCs)** | GLA | The boundaries of these protected sites. These sites are protected because they represent a site of high nature conservation value and are therefore a good measure of where the best quality wildlife habitat is in London. |
| **Areas of Deficiency (AoD)** | GLA | Areas that are not within walking distance of a publically accessible SINC and therefore indicate areas where people may be least likely to easily engage with local nature. |
| **Heat index score** | GLA | A 3 band score was given to each LSOA based on an underlying 1km grid of temperature measurements (>19°, 18°, less than 18°) recorded during the August 2003 heat wave. This broadly indicates areas of Greater London that are likely to experience these kinds of temperature increases in extreme weather events due to climate change. |
| **Open space** | GLA | Areas of accessible open space as defined by GLA rolling programme of habitat survey. Includes parks, public formal gardens, recreation grounds, allotments, nature reserves etc. |

**Table 3.1** – Map layer information

**Map 1** – Communities with a rich garden and open space landscape. LSOAs where:

- There are many garden polygons
- Garden polygons tend to be large
- There is other near-by quality habitat (SINC)
- There are relatively large blocks of continuous garden land

This model allows users to see areas where people live in proximity to quality wildlife habitats (i.e. SINCs), where the area and availability of garden land per dwelling is relatively high and the overall area of garden is relatively large. Gardens in these LSOAs may be supplementing or extending other local wildlife habitats.

At a landscape level the character of these areas is most likely to include large areas of wildlife habitat and garden land, providing the community with good access to green space and nature. Findings in Study 1: Garden Land Cover of this project suggest that over half of the garden land in these LSOAs may be vegetated (depending on the types and sizes of component gardens) – so large areas of multiple gardens could represent an important habitat for wildlife locally in addition to local SINCs and other green space. We don't know the quality or connectivity of the garden habitats involved without surveying directly on the ground. However, we can tentatively infer the habitat potential in the highlighted areas of this model based on garden polygon size. Study 1: Garden Land Cover of this project found that habitat availability tends to be greater in larger garden plots, and smaller garden plots often have a more significant hard surfaced component than larger garden plots. Therefore we assumed that neighbourhoods with typically large garden polygons in our model are likely to have larger garden plots with a greater variety and area of land covers and potentially better habitat availability than other areas.

The people who live in LSOAs highlighted by this model may be particularly interested to know about how their garden fits in with the local landscape of habitats and protected wildlife sites. They already have access to nature and green space and their gardens may hold a diversity of habitats. Therefore engagement with the wider landscape represents an ideal mechanism for motivation. Encouraging the owners of gardens that connect with neighbouring gardens or other green space to view their plot as part of a wider potential wildlife habitat may encourage further wildlife habitat provision or the employment of environmentally-friendly management techniques by garden owners.

**Map 2 –** Where the role of gardens for health and welfare may be most significant. LSOAs where:

- There are many garden plots
- There is not much other open space
- A large proportion of the LSOA has poor access to nature
- IMD is high

This map highlights the people for whom private gardens may be their main source contact with wildlife or semi-natural habitats. These gardens are candidates for protection and enhancement on the grounds of their potential social and health benefits as well as potential value for biodiversity. By selecting areas with relatively little open space or access to nature sites, but numerous garden polygons, the model highlights neighbourhoods where the most significant source of green space and access to nature is likely to be private gardens. Gardens here, as elsewhere, may be important for the mental well-being of local people as well as public engagement with nature conservation and environmental issues. But the importance of gardens' health and welfare role is heightened here by the lack of other sources of contact with green space and wildlife locally. With poor access to public (semi-) natural green spaces, private gardens in these areas may also be providing people here with a resource for outdoor physical exercise that is not available locally. Where IMD is high, economic and health problems are at a higher than average level and therefore increase the value or potential of these gardens as a space for exercise and relaxation.

Even if the value of these gardens for wildlife is lower than in other areas (garden plots may be relatively small and more isolated from other gardens or green space) their social value is likely to be relatively high. An emphasis of the social and health roles of gardens and the compatibility of these functions with the encouragement of wildlife will be a good engagement method for people or policy makers in these areas and encourage protection and improvement of the resource.

**Map 3** – Area with least access to nature and gardens.  LSOAs where:

- There are few garden polygons
- Garden polygons tend to be small
- There is not much other open space
- A large proportion of the LSOA has poor access to nature
- IMD is high

This map shows areas that have low density of green space and wildlife habitats, including gardens. Open space and access to SINCs was used as the measure of green space availability. People in these LSOAs are likely to have more limited visual or physical access to green space or nature than in other areas of London. The reasons for this are likely to be locally determined, with regard to development history. Areas were also preferentially selected where IMD was relatively high, therefore selecting neighbourhoods where people would most benefit from the health and well-being role of green space including gardens.

People in these LSOAs are less likely to be easily engage with gardening for wildlife initiatives as relatively few people have gardens and contact with wildlife may be limited. Socio-economic problems are likely to be of greater priority to people. The regions highlighted by this model may help to explain where take-up of nature conservation campaigns is lower. The model also highlights candidate areas for the inclusion of quality green space, including new gardens, in any future developments, priority for access to currently inaccessible open spaces, or involvement in a community gardening based activities to increase access to garden land and nature.

**Map 4** – Where people could focus on greening up their gardens for climate adaptation measures. LSOAs where:

- Garden polygons tend to be small (likely to be a greater proportion of hard surfacing)
- There is a high heat index score
- There is a small area of other open space

LSOAs which have been shown to have large temperature increases during heat waves may be most likely to experience the most extreme temperature changes due to likely climate change effects. This map therefore demonstrates where people are likely to experience the highest temperatures due to the likely effects of climate change. Garden habitats in these areas will come under most pressure from increased temperatures and 'climate friendly' garden planting, design and management are therefore a greatest priority for these areas.

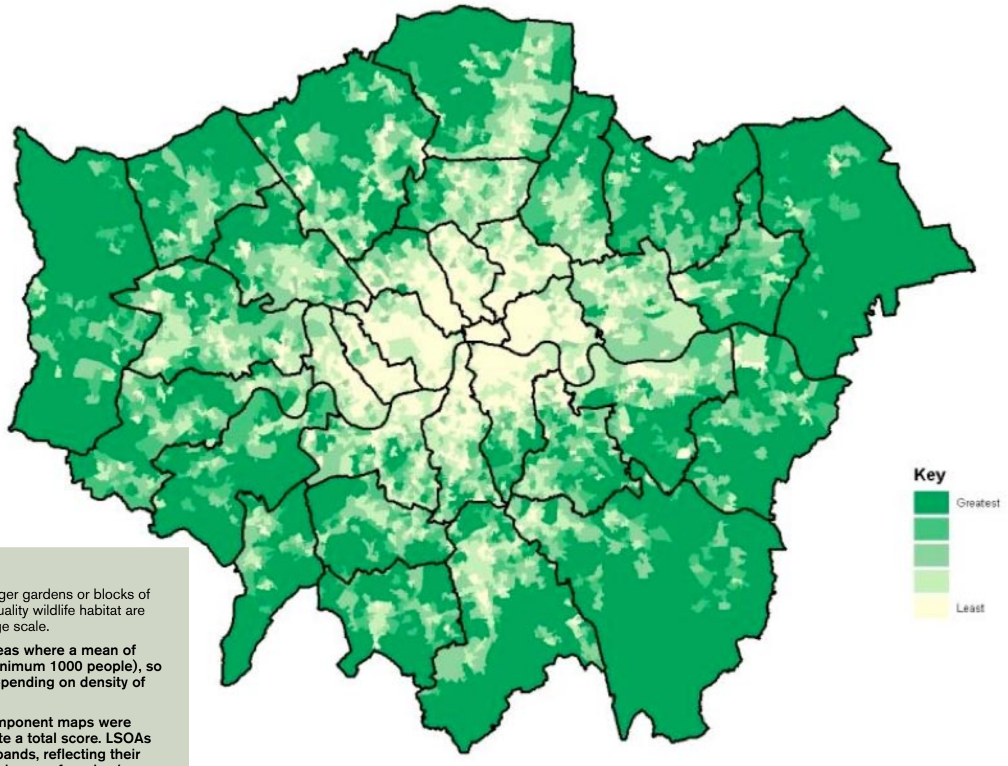
Hard surfaces in built up areas contribute to the trapping of heat and a reduction of the cooling effects of evaporation from soils. Areas with few open spaces and limited vegetation are likely to suffer most from increased temperatures in the future. This model therefore selects LSOAs with relatively little open space. The findings in Study 1: Garden Land Cover indicate that not only are smaller garden plots likely to have a larger proportion of hard surfaces than larger garden plots, but where hard surfacing is being laid in London's gardens it tends to be at the expense of vegetation. Neighbourhoods with typically small garden polygons are therefore selected in this model too, as they are likely to have a reduced complement of vegetated habitats and greater proportion of hard surfacing than other areas.

In areas where these factors coincide, garden owners could help to aid climate change comfort and adaptation in their locality by changing their garden management and planting regime. Local Authorities and charity organisations could help by providing education and resources to facilitate this. Advice on how to vegetate and green-up hard surfaces and plant suitable species to grow in higher daytime temperatures, as well as emphasis of the negative impacts of hard surfacing, may be most important to target at these LSOAs.

# Maps

### London: Garden City?

**Map 1: Communities with a rich garden and open space landscape**




**Interpretation Box**

LSOAs with many, larger gardens or blocks of garden and near by quality wildlife habitat are represented on a range scale.

**LSOAs represent areas where a mean of 1500 people live (minimum 1000 people), so areas vary in size depending on density of settlement.**

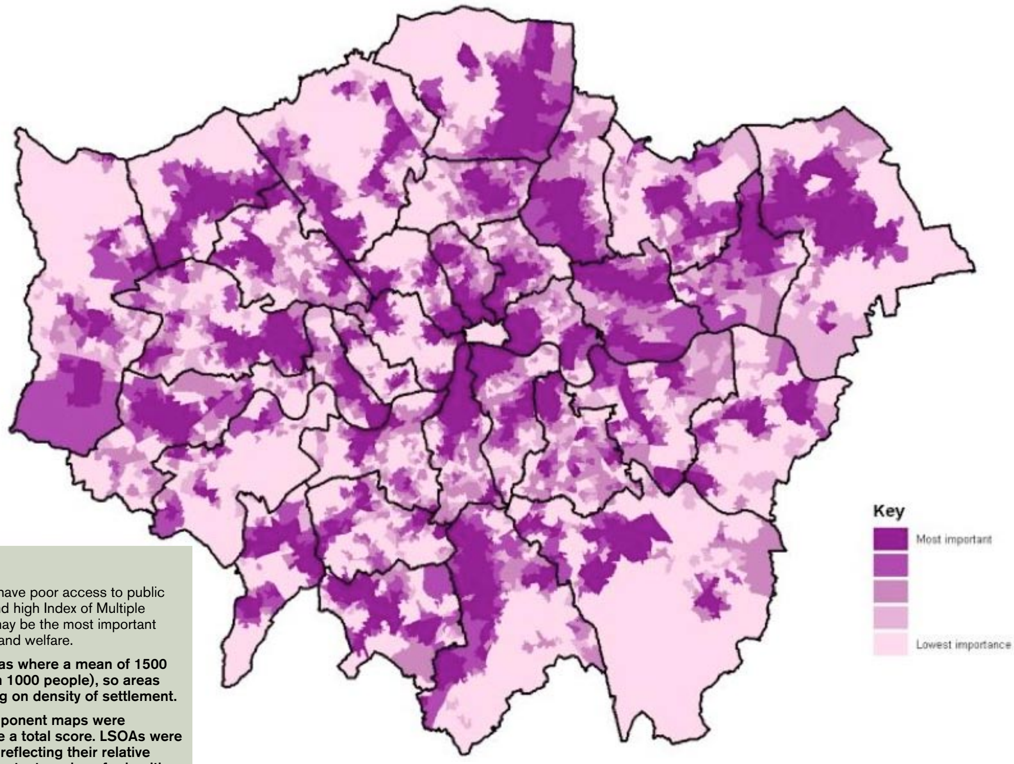
**The scores from component maps were combined to generate a total score. LSOAs were divided into 5 bands, reflecting their relative scores for richness of garden/open space land.**

**Scale 1:2000000**

Produced by Greenspace Information for Greater London

### London: Garden City?

**Map 2: Where the role of gardens for health and welfare may be most significant**




**Interpretation Box**

LSOAs where people have poor access to public sites of nature value and high Index of Multiple Deprivation, gardens may be the most important greenspace for health and welfare.

**LSOAs represent areas where a mean of 1500 people live (minimum 1000 people), so areas vary in size depending on density of settlement.**

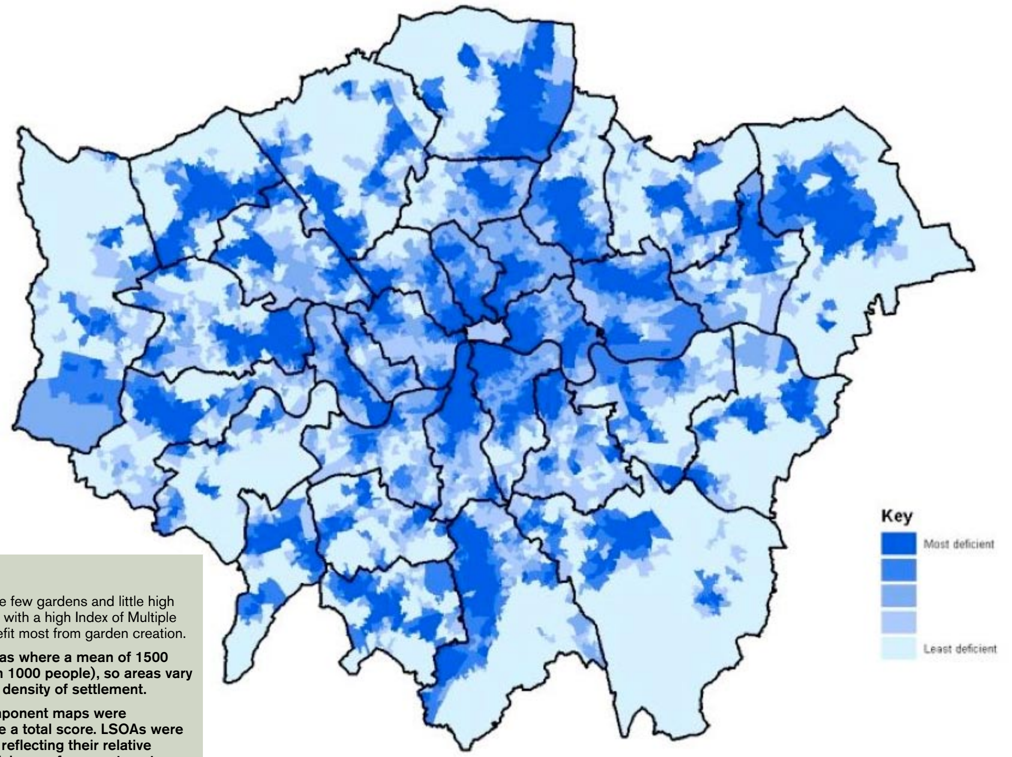
**The scores from component maps were combined to generate a total score. LSOAs were divided into 5 bands, reflecting their relative scores regarding important gardens for health and welfare.**

**Scale 1:2000000**

Produced by Greenspace Information for Greater London

## London: Garden City?

### Map 3: Areas with least access to nature and gardens




**Interpretation Box**

LSOAs where there are few gardens and little high quality habitat coupled with a high Index of Multiple Deprivation could benefit most from garden creation.

**LSOAs represent areas where a mean of 1500 people live (minimum 1000 people), so areas vary in size depending on density of settlement.**

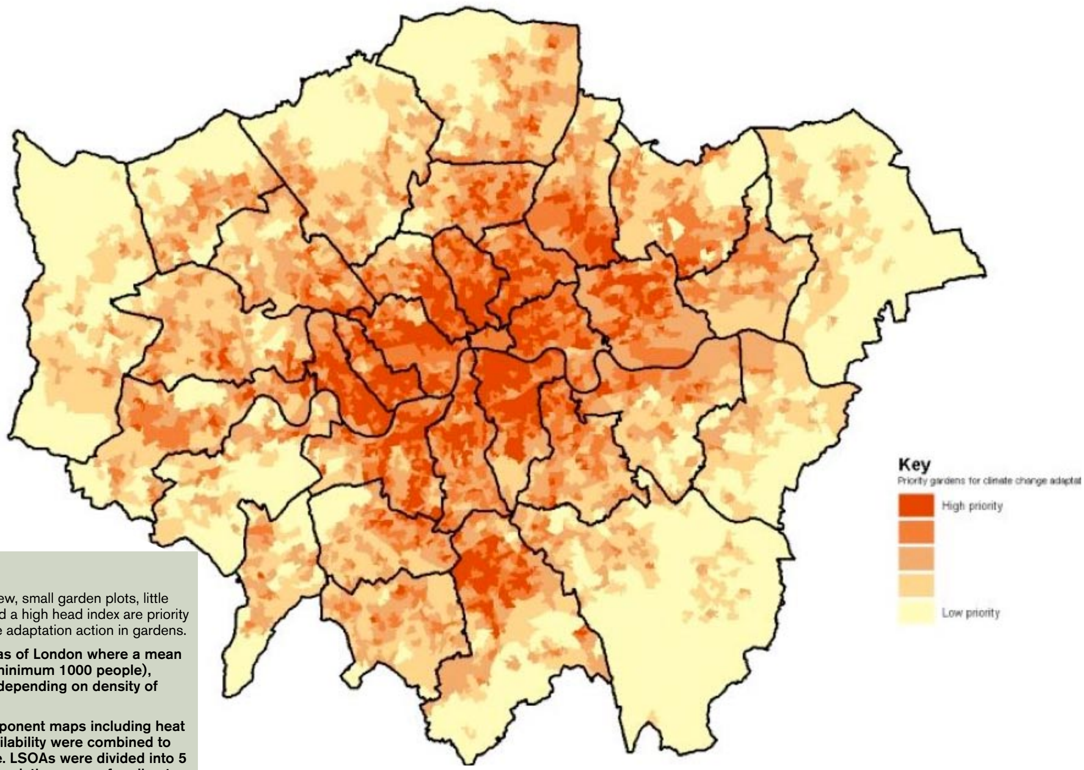
**The scores from component maps were combined to generate a total score. LSOAs were divided into 5 bands, reflecting their relative scores regarding deficiency of access to nature and gardens.**

**Scale 1:2000000**

Produced by Greenspace Information for Greater London

## London: Garden City?

### Map 4: Focus areas for climate adaptation measures in gardens




**Interpretation Box**

LSOAs with relatively few, small garden plots, little near by open space and a high head index are priority for encouraging climate adaptation action in gardens.

**LSOAs represent areas of London where a mean of 1500 people live (minimum 1000 people), so areas vary in size depending on density of housing.**

**The scores from component maps including heat Index and garden availability were combined to generate a total score. LSOAs were divided into 5 bands, reflecting their relative scores for climate adaptation priority.**

**Scale 1:2000000**

Produced by Greenspace Information for Greater London

## Conclusions

This part of the project has demonstrated that there are a number of data sources available for London that can be meaningfully weighted and visualised within a Geographic Information System model to provide functional maps.

**Map 1** indicates that when LSOAs are closer to the city centre, garden polygons within them tend to be fewer, smaller, constitute smaller patches, and are less likely to be near a SINC. This does not mean that gardens nearer the city centre are less valuable (see below) but that they are perhaps less likely to constitute large areas of habitat with biodiversity potential at a landscape level. The mapping provides a means of assessing different areas with regards to their garden resource without relying too heavily on arbitrary inner and outer London distinctions. A local campaign focusing on engagement with near-by SINCs and emphasising the potential for gardens to form large patches of vegetated habitat within the local landscape would be most effectively focused at the LSOAs scoring most highly on this model.

**Map 2** indicates parts of the population that may be benefiting most from the health and well-being value of their gardens. These areas do not show such a concentric distribution as the high scoring LSOAs in map 1. This map gives a strong indication of LSOAs where gardens may represent the only local green space that is accessible and where the Index of Multiple Deprivation is also relatively high. People in these gardens may be less engaged with local green space issues, as there may be little to get involved with, but they may benefit from having access to nature in their gardens. A focus on encouraging wildlife into gardens for pleasure and engagement with nature and an emphasis of gardens as a space to relax and exercise are particularly important approaches to consider for these LSOAs. Funding streams based on the health and welfare agenda may be most appropriate to support garden and wildlife work within these local communities.

**Map 3** shows where LSOAs may benefit most from creation of more gardens or improved access to gardening projects or other green spaces because there is relatively little other green space and poor access to nature and relatively few gardens, but a high IMD. Many of these areas are located in inner London; however, there are pockets of highly scoring LSOAs across most boroughs. The reasons for these conditions are likely to vary, but where these LSOAs include high density residential areas creation of garden space could provide an important access to green space for residents as well as providing additional wildlife habitat. Local initiatives to engage people in gardening or wildlife activities at a community level may be well targeted here to improve overall access to nature and the inherent social benefits.

**Map 4** illustrates the areas of London that are likely to be most affected by temperature increases as suggested by heat wave temperatures and a relative lack of green space or large gardens. The map shows that LSOAs nearer to the city centre are most likely to be priority considerations for improving climate adaptation measures. Outer boroughs are currently better endowed with green space and garden resources, but these must also be protected to maximise their role in climate adaptation for the city.

It is most immediately important to engage people in high priority LSOAs with climate adaptation measures for their gardens such as increasing vegetation, reducing hard surfacing (especially impermeable substrates) and planting appropriate, climate-tolerant plants. But also, people in low priority LSOAs should have the role of their garden green spaces for climate adaptation emphasised to highlight their strategic value and encourage protection.

These four models provide a basis for generating more sophisticated modelling in the future, driven by the specific concerns or needs of organisations. This is likely to be aided by more advanced or detailed data sets, for example, better climate change modelling. Geographic information can be valuable in determining priorities for campaigning and public engagement in particular.

## Recommendations for future study

There are areas within this wide ranging study that would be of interest to explore further for future work. There are also potential new outputs that could be of use to project partners.

The *London: Garden City?* study has documented the scale and diversity of garden land in London. We now have a baseline of information to raise awareness of the value of gardens in London. Though there is great interest in protecting and enhancing gardens (for their varied benefits for wildlife and people - which will be encouraged by this project), the large amount of land involved and the variable situations in different parts of London make this task daunting – a more localised approach is therefore a useful next stage, and may be of interest to other potential users, for example London borough Local Authorities. Some potential initiatives can only be implemented at a local (borough, or neighbourhood level).

The change observed in hard surfacing and vegetation over the study period is likely to have been predated by earlier changes, suitable photographs were unavailable to assess, but different methods could be employed to study change pre 1998 and its drivers. Social influences and drivers were not considered and a correlation of people's attitudes to garden change would also provide insights in future work. In particular, understanding the reasons why people are choosing paving over vegetated land cover will be of help to encourage best practice for wildlife and climate change considerations.

The project (study 3) has demonstrated how it is possible to integrate topological information about gardens with social and environmental data sets to geographically highlight parts of the population where certain conditions are present. This information provides evidence of local conditions compared with other areas of London. Further refining GIS models, in accordance with user needs, is therefore a possible area of future work.

This would, for example, include:

- updating existing data layers generated for this project;
- improving accuracy of the garden layer with new data sets and/or information derived from the garden research project (e.g. the number of front vs. back garden plots);
- exploring different divisions of variation; and different scoring of model variables depending on the user.

One aim of future work could be to help London boroughs to revise their local Habitat Action Plans, which would require a more detailed investigation of variation of the garden resource within boroughs.

The project (study 2) was able to assess the changes to garden land as a consequence of new built development. However, the more detailed investigation of permitted development of buildings on garden land has not been fully possible (study 1 and 2). The findings from across London have identified that outbuildings in gardens have increased in area over time (study 1), and actually that this trend has caused a greater loss of green space than that of new known housing developments granted planning permission on garden land. The use of these garden buildings is not known, though they are likely to be for storage and leisure. A study focusing on this issue would be of interest to bridge this gap and understand more fully the nature of the buildings that have led to a substantial loss of green space from London's gardens.

# Appendix 1

## Appendix 1.1

**Master Map information**

**OS MasterMap® Topography Layer**

Topography Layer is a detailed, intelligent, geographic database. It contains almost half a billion features from the built and natural landscape of Britain.

Detailed and surveyed to a high degree of accuracy, the Topography Layer is continually revised to incorporate changes to the urban and rural environment. It consists of nine themes: land area classifications; buildings; roads, tracks and paths; rail; water; terrain and height; heritage and antiquities; structures; and administrative boundaries.

The Topography Layer forms the foundation of OS MasterMap, and can be used in isolation or together with the Address Layer, Integrated Transport NetworkTM (ITN) Layer and Imagery Layer, to provide a consistent, analytical or reference framework.

Every feature within the Topography Layer has a unique common reference (a TOID®), which enables full integration with the other layers of OS MasterMap and also the association of your own or third party data. Information can then be shared with assurance across different business applications and organisations that have a need for large-scale data.
*http://www.ordnancesurvey.co.uk/oswebsite/support/index.html*

## Appendix 1.2

**Ground Truth survey study**

Ground truth surveys were carried out to: a) identify suitable categories for data collection; b) develop identification guidelines and therefore improve accuracy of land cover estimates at the data collection phase; and, c) identify limitations in aerial interpretation.

## Methods

**Ground surveys**

A convenience sample of gardens (n=21) within Greater London was generated for ground truth survey from London Wildlife Trust volunteers. Volunteer gardens were visited by the project officer and a volunteer during January 2008. Gardens were digitally photographed from different angles, and where possible, from a height. The relative proportions of different land cover surfaces were noted and sketched onto a base map of the MasterMap® boundary for each garden. Maps were annotated to identity features and surfaces present.

The sample selected for ground truth survey is likely to be biased towards people who are interested in wildlife and gardening issues. However, this is not considered to constrain the usefulness of the ground truth surveys, as a variety of common garden surfaces and planting was present in these gardens.

Not all habitats present within a garden are visible on aerial photographs due in part to the angle of the image. Scale, resolution, shadows that obscure detail and overhanging features may obscure the detail of some features in gardens. Most features are visible from the ground, therefore ground truth survey data allows the correct identity of habitats that are visible on aerial photographs to be established, but not the direct comparison of area coverage.

The aerial photographs used in this study represent spring to summer vegetation growth within gardens; however, it was necessary to undertake ground truth surveys during the winter when fewer plants are in leaf. This represents a minor limitation to comparisons of aerial photographs and ground truth habitats. Surveyors therefore used botanical and horticultural knowledge and information from garden owners to supplement observations where possible.

### Aerial photograph comparison

A list of features and habitats possibly of interest to the study was drawn up and the presence or absence of these was interpreted from the 2006-08 aerial images of the sample gardens. Then the presence or absence of the features was checked against the ground truth data (sketch maps, notes and digital photographs). It was noted if the identity of each feature inferred from the aerial photograph agreed with the ground truth maps and photographs, or if not, why this feature was not identified. The direct comparison of records from each garden to aerial photographs also enabled a number of rules to be defined to aid identification of categories.

Ground truth data was available only on the current status of gardens. Therefore survey information was only used to verify photograph data from 2006-08. For the development of suitable categories of data collection, ability to identify surfaces and features on the 1998-99 photographs was necessary and identification of habitats is likely to be more difficult from the older photographs, where boundaries and textures were less clear due to poorer resolution. Therefore, although ground truth evidence was not available to corroborate observations for the earlier photographs, these were consulted throughout to ensure land cover categories could be identified on each photograph series.

### Results

Many garden features and habitats were correctly identifiable, although some were only identifiable at a broader category level. Some features are not easily identifiable. Suitable categories for data collection were developed from this information. The chart below illustrates these findings for each habitat or feature surveyed.

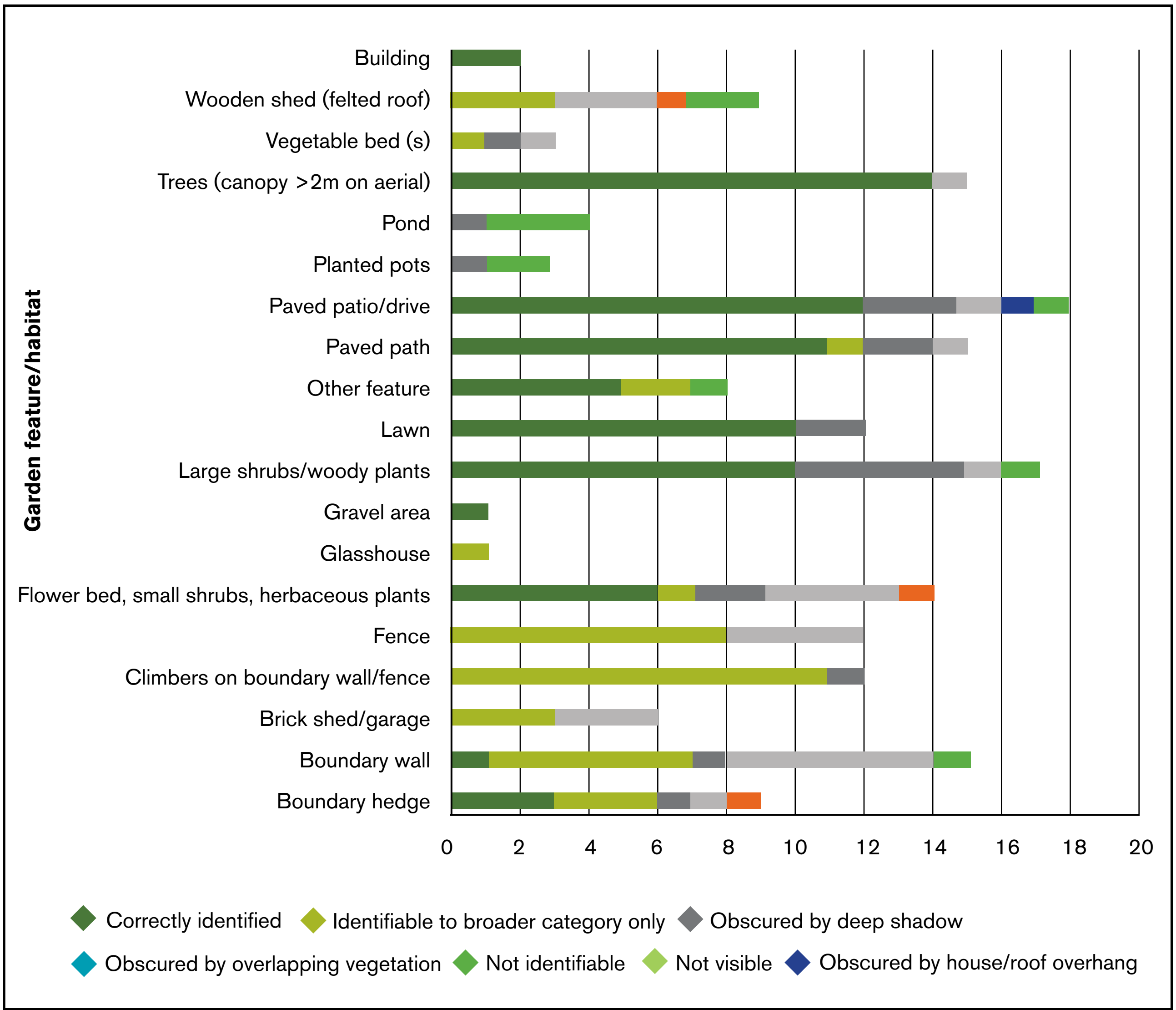
Features with a high rate of correct identification were considered to be appropriate data collection categories. These features and habitats included: trees, hard surfaces and lawns. Hard surfaces of different permeability were not easily distinguishable, in particular on the older photographs. It was therefore decided to group all types of hard surfacing (patios, driveways, pathways and gravel) into a single category.

Features that showed a high incidence of visibility on aerial photographs but that were often not distinguishable from each other were grouped into larger categories to improve overall rate of correct identification. For example, walls or fences that were covered in climbers were visible on the aerial photographs in most gardens where they occurred, but were difficult to distinguish from hedges or shrubs.

Some features were rarely or never identifiable correctly and these were considered not to be suitable to record. Ponds, planted pots and vegetable plots were not identified correctly on the aerial photographs of any garden where they occurred. Vegetable plots were not easily distinguishable from planted borders so these were grouped into that category.

Shadow and overlapping vegetation affected most categories in at least one garden and are likely to lead to some loss of detail, this represents a known limitation to the method of aerial interpretation.

Three distinct classes of vegetation and three other categories of surfacing or structures were defined. A category ‘other’ land cover was also necessary to account for rarer garden features or habitats that do not fit into a major category. A category ‘unknown’ land cover was used for areas of garden where features were obscured by shadow, photograph angle or blur. To minimise the effects on the overall data set, a threshold upper limit of 20% ‘unknown’ land cover was set to exclude those gardens where data loss was too great. From this, it appears that tree canopy and tall built structures were most readily distinguished from the aerial photographs, and least likely to be obscured. This is likely to have led to some small overestimation of these two land cover categories in comparison with the others, despite the grouping used to minimise this.




The chart illustrates the ability to correctly identify various features or habitats present in the ground truth gardens on the corresponding 2006-08 aerial photograph

## Appendix 1.3
## Note on the classification of buildings

### Small buildings

Garden buildings recorded in this study were those that were not categorised as building by MasterMap® but visibly within the garden boundary on the aerial photograph. The MasterMap® Topography Layer defines a building as, "roofed constructions, usually with walls and being permanent. This includes permanent roofed-constructions that exceed 8.0m² in area (12.0m² in private gardens). Exceptions are made to this area rule for smaller buildings that, due to their detached position, form relatively important topographic features." (Ordnance Survey, 2009, pp.29). This means that most garden buildings less than 12m² will not be classified as building by MasterMap®, but will be classified as building by this project methodology. The building category defined in Study 1: Garden Land Cover mainly includes relatively small structures such as wooden sheds and glasshouses.

### Change updates

MasterMap® reflects losses, gains or modifications to topographical features according to defined life-cycle rules (Ordnance Survey, 2009). However, not all real-world changes will be reflected in MasterMap® as changes, for example, "addition of a new porch to a house would usually be considered too minor a change for Ordnance Survey data capture" (p.19). Where such changes to the exterior of a building are not captured by MasterMap® but appear on the aerial photograph within the garden boundary these will be defined as a building according to the category definition of this project, so for example, a new porch encroaching into the garden space would be classified as a building in this project (both study 1 and 2).

**Extensions**

Certain Topography Layer features are updated with all changes that have occurred within six months of completion of construction (for less significant land cover on a rolling 2-10 year basis), according to the current MasterMap® revisions programme as outlined in the Ordnance Survey revision policy for this product (see Ordnance Survey, Revision policy for basic-scale products, Information Paper: available at *http://www.ordnancesurvey.co.uk/oswebsite/aboutus/foi/docs/basicscalerevisionpolicy.pdf)*. This policy applies to new housing and associated features, however, extensions to private dwellings are excluded from the continuous revision process. Detail of, "extensions to private residential buildings", and, "permanent buildings in private residential gardens, built after initial development", (p.3) is captured as necessary to sensibly complete any revision of other features subject to continual or cyclic revisions, but is not currently captured otherwise. This revision policy was changed in 2007-08. It is not clear what the status of building extensions or new buildings in private residential gardens was prior to these changes and therefore at the time of data capture for the topographical data used in this project (June 2006).

This means that the category of a building used in Study 1: Garden Land Cover of this project includes a mixture of building types and is not wholly consistent over time. We can be confident that all non-permanent buildings (such as sheds) that are less than 12m² and extensions that were added to houses after June 2006 are included in the building category of this project. However, extensions built prior to this date may not be included as they may have been classified as a building by MasterMap®. This is unfortunate given the interest in small scale permitted developments and extensions, especially as these are not covered by the study of London Development Database developments in study two.

## Appendix 1.4

Total areas of land cover types (to 2 significant figures) in 1998-99 and associated proportions (with unknown category proportionally distributed) for London, and for different garden types.

| Land cover type | Total area (ha) | % of garden area | % of London | Total area in Front garden plots (ha) | % of front garden plot area | Total area in back garden plots (ha) | % of back garden plot area | Total area in 'other' garden plots (ha) | % of 'other' garden plots area |
|---|---|---|---|---|---|---|---|---|---|
| All land | 37900 | 100% | 24% | 9400 | 100% | 24000 | 100% | 4600 | 100% |
| Tree canopy | 7200 | 19% | 5% | 890 | 9% | 4900 | 20% | 1400 | 30% |
| Lawn | 13000 | 34% | 8% | 2300 | 24% | 9200 | 38% | 1600 | 35% |
| Mixed vegetation | 4400 | 12% | 3% | 1100 | 12% | 3000 | 13% | 300 | 7% |
| Total 'green' land covers | 25000 | 66% | 16% | 4300 | 46% | 17000 | 71% | 3300 | 72% |
| Hard surface | 9900 | 26% | 6% | 4700 | 50% | 4200 | 18% | 1000 | 22% |
| Buildings | 1800 | 5% | 1% | 67 | 1% | 1600 | 7% | 140 | 3% |
| Side passage | 600 | 2% | 0% | 100 | 1% | 500 | 2% | 14 | 0% |
| Other | 890 | 2% | 1% | 200 | 2% | 600 | 3% | 90 | 2% |

## Appendix 1.5

Changes in area of land cover categories (ha) for all gardens (with unknown land cover distributed proportionally) and different types of garden, between 1998-99 and 2006-08

| **Land cover type** | **Total change (ha)** | **% of original area** | **Change in front gardens** | **% of original** | **Change in back gardens** | **% of original** | **Change in 'other' gardens** | **% of original** |
|---|---|---|---|---|---|---|---|---|
| Tree canopy | -500 | -7% | -150 | -17% | -240 | -5% | -110 | -8% |
| Lawn | -2200 | -17% | -700 | -30% | -1300 | -14% | -130 | -8% |
| Mixed vegetation | -390 | -9% | -170 | -15% | -220 | -7% | 6 | 2% |
| Total 'green' land covers | -3000 | -12% | -1000 | -23% | -1800 | -11% | -230 | -7% |
| Hard surface | 2600 | 26% | 1100 | 23% | 1200 | 29% | 270 | 27% |
| Buildings | 1000 | 56% | 56 | 84% | 940 | 59% | 5 | 4% |
| Side passage | -23 | -4% | 0 | 0% | -22 | -4% | 0 | 0% |
| Other | -550 | -62% | -180 | -90% | -320 | -53% | -40 | -44% |

## Appendix 1.6

Statistical analysis of change in percentage cover between garden plots in 1998-99 and 2006-08 and within each garden plot type category. These tests were performed on raw percentage cover data for all land cover categories in plots where change occurred (i.e. zeros and ties eliminated). There were too few incidents of change (excluding zero values) to test 'other' land cover and side passage in all types of garden plot and too few incidents of change in building in front and 'other' types of garden plot to test.

| **Land cover type** | **Type of garden** | **T** | **P value** |
|---|---|---|---|
| Lawn | Front | 2.9489 | 0.003818 |
| | Back | 7.9318 | <0.0001 |
| | Other | 2.58 | 0.01253 |
| Hard surface | Front | -8.1221 | <0.0001 |
| | Back | -8.3339 | <0.0001 |
| | Other | -1.4822 | 0.1450 |
| Building | Back | -8.108 | <0.0001 |
| Unknown | Front | 2.7859 | 0.005987 |
| | Back | 3.4626 | 0.0006102 |
| | Other | 1.7723 | 0.0815 |

## Appendix 1.7

Numbers of garden trees in London scaled up from average tree density observed in garden plots, and change in this number over the study period.

| | Current (2006-08 estimate) | Change (since 1998-99) |
|---|---|---|
| | Total number of garden trees (millions, 2sf) | |
| All gardens | 2.5 | -0.03 |
| Front gardens | 0.4 | -0.02 |
| Back gardens | 1.9 | 0.02 |
| Other gardens | 0.3 | -0.03 |
| | Average number of garden trees per garden (2sf) | |
| Any garden | 0.2 | -0.01 |
| Front garden | 0.2 | -0.01 |
| Back garden | 1.1 | 0.01 |
| Other garden | 1.0 | -0.11 |

## Appendix 1.8

Total areas of land cover types in 2006-2008, with unknown areas not distributed.

| **Land cover type** | **Total area (ha)** | **% of garden area** | **% of London** | **Total area in Front garden plots (ha)** | **% of front garden plot area** | **Total area in back garden plots (ha)** | **% of back garden plot area** | **Total area in 'other' garden plots (ha)** | **% of 'other' garden plots area** |
|---|---|---|---|---|---|---|---|---|---|
| All land | 37900 | 100% | 24% | 9400 | 100% | 24000 | 100% | 4600 | 100% |
| Tree canopy | 6000 | 16% | 4% | 680 | 7% | 4200 | 18% | 1200 | 26% |
| Lawn | 9900 | 26% | 6% | 1500 | 16% | 7000 | 29% | 1300 | 28% |
| Mixed vegetation | 3600 | 9% | 2% | 850 | 9% | 2500 | 10% | 250 | 5% |
| Total 'green' land covers | 20000 | 53% | 13% | 3000 | 32% | 14000 | 58% | 2800 | 61% |
| Hard surface | 11000 | 29% | 7% | 5300 | 56% | 4800 | 20% | 1200 | 26% |
| Buildings | 2500 | 7% | 2% | 110 | 1% | 2300 | 10% | 130 | 3% |
| Side passage | 530 | 1% | 0% | 90 | 1% | 430 | 2% | 10 | 0% |
| Other | 310 | 1% | 0% | 10 | 0% | 250 | 1% | 40 | 1% |

## Appendix 1.9

Total areas of land cover types in 1998-1999 with unknown areas not distributed

| Land cover type | Total area (ha) | % of garden area | % of London | Total area in Front garden plots (ha) | % of front garden plot area | Total area in back garden plots (ha) | % of back garden plot area | Total area in 'other' garden plots (ha) | % of 'other' garden plots area |
|---|---|---|---|---|---|---|---|---|---|
| All land | 37900 | 100% | 24% | 9400 | 100% | 24000 | 100% | 4600 | 100% |
| Tree canopy | 6400 | 17% | 4% | 800 | 9% | 4300 | 18% | 1300 | 28% |
| Lawn | 12000 | 32% | 8% | 2100 | 22% | 8100 | 34% | 1400 | 30% |
| Mixed vegetation | 3900 | 10% | 2% | 990 | 11% | 2700 | 11% | 240 | 5% |
| Total 'green' land covers | 22000 | 58% | 14% | 3900 | 41% | 15000 | 63% | 2900 | 63% |
| Hard surface | 8800 | 23% | 6% | 4200 | 45% | 3700 | 15% | 900 | 20% |
| Buildings | 1600 | 4% | 1% | 60 | 1% | 1400 | 6% | 120 | 3% |
| Side passage | 540 | 1% | 0% | 91 | 1% | 440 | 2% | 12 | 0% |
| Other | 780 | 2% | 0% | 180 | 2% | 530 | 2% | 79 | 2% |
| Unknown | 4300 | 11% | 3% | 940 | 10% | 2800 | 12% | 560 | 12% |

## Appendix 2

Tests for a difference in land cover areas before and after development by Wilcoxon signed rank test with continuity correction.

| Land cover type | Wilcoxon test statistic | P value | Statistically significant? |
|---|---|---|---|
| Tree canopy | 43728 | <0.0001 | Yes |
| Lawn | 54454 | <0.0001 | Yes |
| Mixed vegetation | 41964 | <0.0001 | Yes |
| Hard surface | 7180.5 | <0.0001 | Yes |
| Building | 11 | <0.0001 | Yes |
| Side passage | 0 | <0.0001 | Yes |
| Other | 846.5 | <0.0001 | Yes |
| Unknown | 39523.5 | <0.0001 | Yes |

# Appendix 2

Tests for a difference in land cover areas before and after development by Wilcoxon signed rank test with continuity correction.

| Land cover type | Wilcoxon test statistic | P value | Statistically significant? |
|---|---|---|---|
| Tree canopy | 43728 | <0.0001 | Yes |
| Lawn | 54454 | <0.0001 | Yes |
| Mixed vegetation | 41964 | <0.0001 | Yes |
| Hard surface | 7180.5 | <0.0001 | Yes |
| Building | 11 | <0.0001 | Yes |
| Side passage | 0 | <0.0001 | Yes |
| Other | 846.5 | <0.0001 | Yes |
| Unknown | 39523.5 | <0.0001 | Yes |

# Glossary of terms

**Contingency table** – A table used to compare counts of individual items (categorical data). Using probability, we can calculate the number expected in each grid square of the contingency table if all items were evenly distributed between the categories. A chi-squared statistic and associated p value can then inform us if the difference between observed and expected values is significantly greater than is explained by chance alone.

**Geographical Information System** - This is a data base of spatial information which allows the user to visualise relationships between data sets on a map. 'Layers' of data can be interrogated to answer a variety of questions.

**Green space** – Any vegetated land or water within or adjoining an urban area. Including: green corridors like paths, disused railway lines, rivers and canals woods, grassed areas, parks, gardens, playing fields, children's play areas, cemeteries and allotments, countryside immediately adjoining a town which people can access from their homes derelict, vacant and contaminated land which has the potential to be transformed (Greenspace Scotland)

**Green infrastructure** – The multifunctional, interdependent network of green spaces, waterways, wetlands and vegetated features (e.g. green roofs) lying within the urban environment and the urban fringe, connecting to the surrounding countryside. It provides multiple benefits for wildlife and ecosystem services for people including: flood management; urban cooling; ecological connectivity; improving physical and mental health; green transport links (walking and cycling routes); and food growing.

**Index of Multiple Deprivation (IMD)** – A ward-level index made up from six ward level 'domain' indices; income; employment; health deprivation and disability; education, skills and training; housing; and geographical access to services. Lower Super Output Area (LSOA) – Standard mapping areas used by the Office of National Statistics, LSOAs each have 1500 to 2000 residents. Four to eight LSOAs make up a council ward.

**Mean** – the arithmetic mean is a measure of central tendency, i.e. the intermediate value that measurements often cluster around. It is the sum of all data values, divided by the number of data values.

**Median** – the median is a measure of central tendency, i.e. the intermediate value that measurements often cluster around. It is the middle value and is found by putting all data values in order of size and selecting the middle value.

**Normal distribution** – when data values cluster more-or-less symmetrically around a central value in a bell-shaped distribution.

**Polygon** – a topographical feature in a Geographical Information System with an enclosed boundary, for example, a garden polygon.

**Private gardens** – domestic, privately owned garden plots associated with residential dwellings. Does not include public gardens, nor those of social landlords.

**Significance (statistical)** – if a result is statistically significant it is unlikely to have occurred by chance alone. The usual cut off is if an event of this magnitude would occur in less than 5% of samples of the kind being considered.

**Transformed data** – data values are transformed by applying a specific function to all data points, for example square root, logarithms or inverse. The reason for transforming data is to alter the shape of the distribution so that it better meets the assumptions of statistical tests and reduces any correlation between the mean and variance of the samples to be compared. A common transformation is to make data more symmetrically distributed, to better approximate the Normal distribution assumed by many statistical tests.

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**London Wildlife Trust** campaigns to encourage Londoners to create wildlife and climate friendly gardens. Every gardener, whether in a private garden or in a communal garden space can make a difference by taking simple actions like digging up hard surfacing and planting a good range of vegetation.

**Greenspace Information for Greater London** is the capital's environmental records centre. It collates, manages and makes available detailed information on London's wildlife, parks, nature reserves, gardens and other open spaces.

The **Greater London Authority** is a strategic authority with Londonwide role to design and deliver a better future for London.

**Royal Society of Wildlife Trusts** There are 47 local Wildlife Trusts across the whole of the UK, the Isle of Man & Alderney, working for an environment rich in wildlife for everyone. With 791,000 members, The Wildlife Trusts are the largest UK voluntary organisation, dedicated to conserving the full range of the UK's habitats and species.