Valuing Ealing's Urban Trees

EALING I-TREE ECO TECHNICAL REPORT

FOREWORD

Ealing's trees are an integral part of the borough's character, from the 400 year old woodlands to the Cherry blossom-lined streets; even the borough's logo sports a tree. Trees can play an important role in promoting mental and physical wellbeing, adding colour and beauty to the built urban landscape, reducing the heat island effect and they have the ability to absorb large quantities of water, to help reduce the risk of flooding. Ealing's trees are becoming increasingly valuable as we face challenges of climate change and population growth. The Council's vision is to increase and enhance the whole of the urban tree stock for the enjoyment of current and future generations and to ensure that trees remain a defining feature of the splendid suburban borough that is Ealing.

One of the overarching themes of the new draft London Plan (December 2017) is creating a healthy city. The Plan suggests that green infrastructure, including trees, must be planned, designed, and managed in a more integrated way to ensure Londoners reap the multitude of benefits it provides, including mental and physical health and wellbeing. The Plan emphases that the urban forest is an important part of London's green infrastructure and a major asset to the urban environment. This report helps us better understand the importance of Ealing's trees and woodlands.

The economic and social value of trees has become increasingly evident across all of London and has been highlighted in the London i-Tree Assessment and the Natural Capital Account for London's public parks and green spaces. This document highlights that all borough trees, both privately and publicly owned, should be considered not as individual trees and woodlands, but managed and regarded as one 'urban forest'. It aims to build on the London i-Tree assessment by serving as the most extensive urban tree survey carried out in a London borough to-date, providing the baseline information and recommendations necessary for long term integrated and planned management of Ealing's urban forest.

This report should act as a rallying call to all those who want to protect and enhance Ealing's tree cover. It is not just a distinctive feature of the borough, but also enhances the quality of life of residents, provides genuine health and environmental benefits and represents a key part of what makes Ealing a great place to live and work. Ealing Council has worked hard to demonstrate its commitment to our borough's trees, a commitment we intend to keep over the coming years to safeguard and grow this vital asset.

Cllr Julian Bell
Leader, Ealing Council

EXECUTIVE SUMMARY

The trees in our urban parks, gardens, housing estates, open spaces, woodlands, streets and transport infrastructure are collectively described as an 'urban forest'. This report provides the most comprehensive study to date on the structure and value of the urban forest across a political geography: the London Borough of Ealing. At the time of publishing, the project is unique in implementing a combination of the i-Tree assessment methods: random sample i-Tree Eco, council inventory i-Tree Eco, and i-Tree Canopy.

1. An unstratified i-Tree Eco study was carried out with 215 randomly allocated tenth of an acre plots across the Borough. This assessment provides a quantitative baseline of the air pollution removal, carbon storage, carbon sequestration, stormwater benefits, and amenity value of the entire tree resource in Ealing, accounting for the trees on both public and private land.

2. i-Tree Eco assessment of Ealing's existing operational tree inventory database provided a detailed picture of the structure, value and ecosystem service benefits of the trees that are actively owned and managed by Ealing Council. Not only does this methodology provide a detailed overview of the council's tree estate but it enables a top line cost benefit analysis of services provided by the council tree department.

3. i-Tree Canopy was used to assess ward level tree canopy cover across the borough. This information compares and contrasts the extent of tree cover between wards within the borough, providing detailed analysis that informs the council and enables borough officers to plan localised tree strategies and canopy cover targets. This information can be presented alongside other social indicators, such as health and well-being or living environment deprivation, to provide further context.

The three strands allow a detailed analysis of Ealing's trees. Ward-level canopy cover is established, the structure and function of Council-owned and managed trees are recognised, the structure and function of the overall urban forest of Ealing is assessed and the benefits accrued are quantified.

This detailed report builds on the London i-Tree report by providing the information necessary for the production of a comprehensive borough management plan for Ealing's urban forest. It provides relevant information and recommendations to inform the council's tree strategy in the short, medium and long-term and provides the baseline information for ward level comparisons.

Benefits of Trees in Ealing

Conserve Energy

Carefully positioned trees can cut heating and cooling requirement in buildings, providing shade in summer and blocking cold winds in winter.

234,400

Trees in Total

Reduce Flood Risk

Trees absorb water, lowering stress on storm water drains and mitigating flood risk. They also improve soil quality and prevent erosion, so more water is held in the ground.

74,440m³

Storm Water Alleviation (per annum)

Support Environmental Education

Planting and caring for urban trees can help to develop awareness, understanding, skills and knowledge about the local environment.

Improve Air Quality

Trees improve air quality by absorbing pollutants and intercepting gases harmful to human health.

Total Annual Benefits

£1.6M

Enhanced Health & Well-being

Trees and green spaces can improve recovery times from illness, reduce stress and boost mental health.

Storing Carbon

As trees grow they accumulate carbon in their woody tissues, reducing the amount of this greenhouse gas in the atmosphere.

76,670

Carbon Storage (tonnes)

Add Character & Charm

Trees add beauty to their surroundings. They bring colour, soften harsh lines of buildings, screen unsightly views and enhance the character of an area.

Strengthen Communities

Creating and caring for green spaces helps people reconnect with their neighbours and surroundings.

Enrich Habitats & Biodiversity

An increase in tree diversity benefits a host of insects, birds and mammals that rely on trees for food and protection. For example, they are an important source of nectar for bees.

Replacement Costs

£259M

Enable Urban Foraging

Trees provide fruits and nuts for wildlife and humans. Community Orchards offer health, social and environmental benefits.

16.9%

Canopy Cover

Fig 1

Key Findings

	Ealing Borough Total		Ealing Council Tree Inventory*	
Number of Trees	234,400#		43,947	
Canopy Cover	16.9%		2.7%	
Most Common Species	*Quercus robur, Fraxinus excelsior, Ulmus minor angustifolia*		*Prunus, Tilia x europaea, Fraxinus excelsior*	
Amenity Value (CAVAT)	£3.4 billion		£1.1 billion	
Replacement Cost	£259 million		£65.2 million	
Total Annual Benefits	£1.6 million		£235 thousand	
Pollution Removal (per annum)#	33 tonnes	£952,000	6 tonnes	£169,000
Storm Water Alleviation (per annum)#	74,440 m³	£113,000	13,060 m³	£19,800
Carbon Sequestration (per annum)#	2,250 tonnes	£527,000	446 tonnes	£28,500
Carbon Storage#	76,670 tonnes	£4,890,000	16,600 tonnes	£1,060,000

Table 1: Headline Figures
*This is a subset of the trees that Ealing Council manage as: 1) Not all council trees are inventoried and 2) Only 58% of the inventoried trees have the minimum data required to run the i-Tree Eco model. See the methods section for more information.
#: estimate, or modeled output.

Notes

Total number of trees measured: The random sample inventory figures are estimated by extrapolation from the sample plots. The council tree inventory figures are derived from the existing council tree inventory.

Tree Canopy Cover: The area of ground covered by leaves when viewed from above.

Replacement Cost: the cost of having to replace a tree with a similar tree using the Council of Tree and Landscape Appraisers (CTLA) Methodology guidance from the Royal Institute of Chartered Surveyors.

Carbon storage: the amount of carbon bound up in the above- ground and below-ground parts of woody vegetation.

Carbon sequestration: the annual removal of carbon dioxide from the air by plants . Carbon storage and carbon sequestration values are calculated based on DECC figures of £64 per metric ton for 2017.

Pollution removal: This is calculated based on the UK social damage costs (UKSDC) and the US externality costs (USEC) where UK figures are not available; £927 per metric ton (carbon monoxide USEC), £16,528 per metric ton (ozone USEC), £64,605 per metric ton (nitrogen dioxide UKSDC), £1,956 per metric ton (sulphur dioxide UKSDC), £178,447 per metric ton (particulate matter UKSDC). USEC prices were converted from the $ values provided by i-Tree Eco using the HMRC average for year (to 31st March 2017) spot rate (£-$ = 1.33 and $-£ 0.75).

Avoided Runoff: Based on the amount of water held in the tree canopy and re-evaporated after a rainfall event. The value is based on an average volumetric charge of £1.516p per m³ and includes the cost of avoided energy and associated greenhouse gas emissions[1].

1. Rogers K., et al. (2012) Green Benefits in Victoria Business Improvement District

**Canopy Cover
Ealing Wards**

Legend:
- 6% - 10%
- 10% - 14%
- 14% - 18%
- 18% - 22%
- 22% - 26%

Northolt Mandeville 21.8%
North Greenford 25.9%
Greenford Green 14%
Northolt West End 16.2%
Greenford Broadway 17.6%
Perivale 15.6%
Hanger Hill 22.8%
East Acton 13.2%
8.3%
Lady Margaret
Cleveland 18.5%
Hobbayne 23%
Dormers Wells 22.4%
Ealing Broadway 12.5%
Acton Central 18.2%
Southall Broadway 10.3%
Elthorne 21.2%
Walpole 20%
Ealing Common 16.3%
South Acton 16%
Norwood Green 15.8%
Southall Green 6.4%
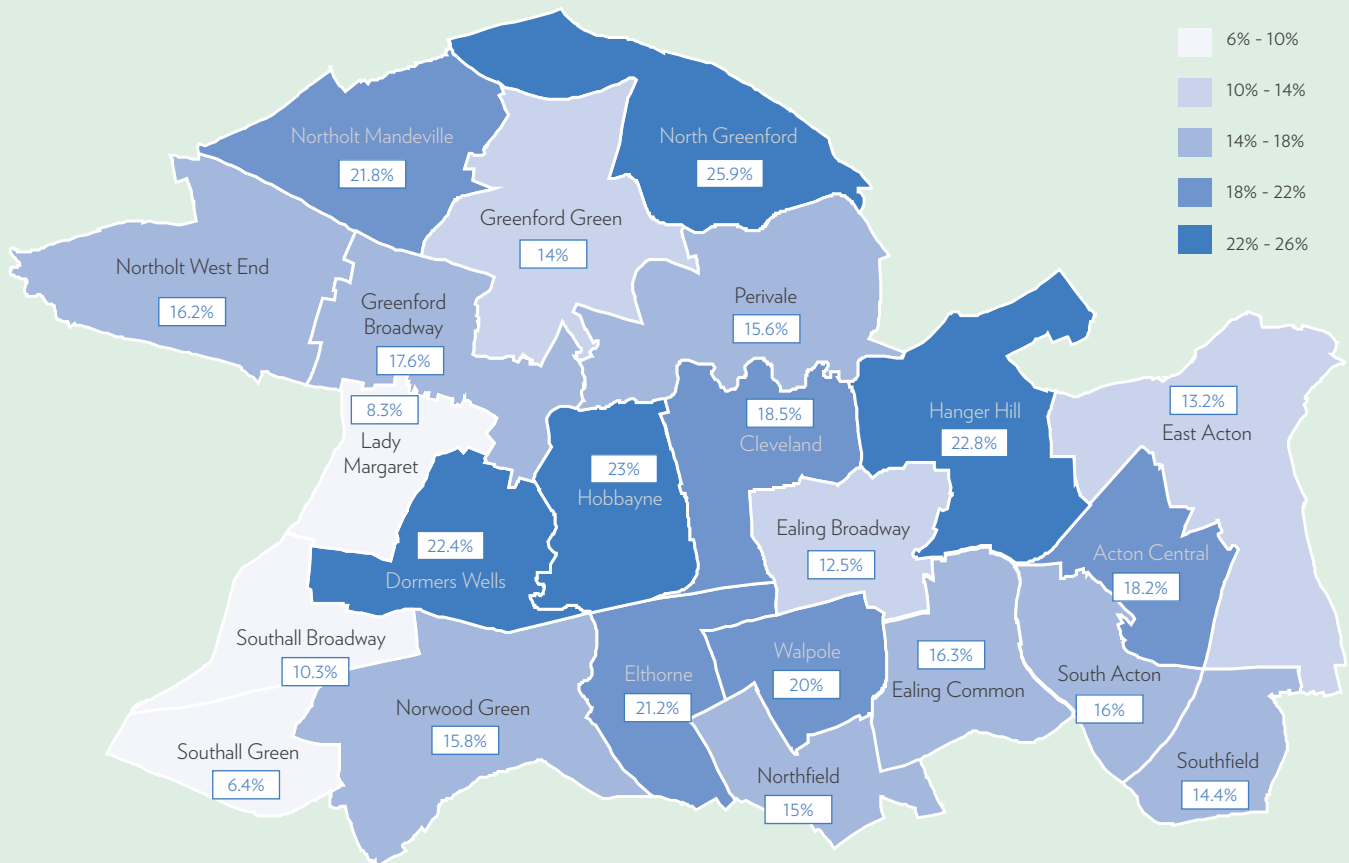Northfield 15%
Southfield 14.4%

Fig 2: Canopy cover across Ealing calculated using i-Tree Canopy

Key Recommendations

This i-Tree study has identified how incredibly valuable Ealing's urban forest is. It has highlighted many positive attributes as well as some key areas for improvement. This section provides a summary of the suggested recommendations given throughout this report, detailing how Ealing Council and its residents could enhance and maximise the benefits Ealing's urban forest delivers.

Section 1: Structure and Composition

1. A wider variety of tree species are planted (with due consideration to local site factors) in wards with lowest diversity to reduce the likelihood and impact from any given pest or disease outbreak.

2. Protection for existing mature and maturing trees is enhanced, together with increasing the planting of large-stature trees, (where possible) to increase canopy cover and the provision of benefits. This should be targeted to those wards with the least tree cover at present.

3. Set a canopy cover goal of increasing tree canopy cover on both public and private land. A suggested goal would be to reach 20% by 2030 as a minimum target across all wards. Part of this goal can be achieved by protecting and growing existing trees (see 2 above).

4. In order to implement and monitor these recommendations, and those that follow in further sections, it is also recommended that:

   i) Ealing Council carries out a systematic and thorough inventory of all the trees under Council ownership

   ii) A strategic urban forest master plan (with a vision for 2100) is produced setting out how these and other recommendations can be measured, targeted to the areas of greatest impact and need, and implemented. It will also set out criteria for a repeat assessment in 5-7 years to monitor progress.

5. Further investigation to establish the opportunities for, and any barriers to, the planting and establishment of trees in the lowest performing wards.

Section 2: Ecosystem Services

6. Local air quality and social indicators such as the indices of multiple deprivation are mapped alongside tree cover to identify spaces and places where the addition of trees could help meet local need in the lowest performing wards.

7. Areas of most need are identified and targeted to investigate for tree planting suitability. The results should also be checked by experts with local knowledge and experience as there may be 'barriers' to tree planting in the identified areas which will need to be addressed.

8. Species are selected that are appropriate to the site to maximise the benefits trees can deliver and to realise the full site potential. Tools such as i-Tree Species can be used to help decision making, but should also be informed by site appraisal. It is essential that trees are planted with some level of community engagement if planting initiatives are to succeed.

9. The development of any tree planting programmes need to be sustainable and to be co-ordinated with other local stakeholders as part of a larger sustainable urban forest masterplan for Ealing.

10. Street and greenspace tree planting is optimised for air pollution removal.

Section 3: Pests, Disease and Tree Health

11. A Pest Outbreak action plan is embedded into future Ealing tree strategies and should consider tree health, how to reduce chance of new threats being introduced (biosecurity), dealing with new outbreaks (contingency planning) and where appropriate how to manage established pests and diseases to maximize benefits delivery

12. To help deliver the overarching aims, tree health has to be addressed; strategies include:

    i) Increasing ward level species diversity

    ii) Implementing an annual inspection programme of vulnerable species to maintain healthy trees

    iii) Implement biosecurity procedures and practices to minimise risk of outbreak

ACKNOWLEDGEMENTS

We wish to thank all land owners and members of the public who granted access to their properties for the collection of the field data, without which there would be no study.

i-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and community forestry analysis and benefits assessment tools, including i-Tree Eco. The Forest Service, Davey Tree Expert Company, National Arbor Day Foundation, Society of Municipal Arborists, International Society of Arboriculture, and Casey Trees have entered into a cooperative partnership to further develop, disseminate and provide technical support for the suite.

Trees for Cities engages people to plant and care for urban trees in cities across the UK. Through planting trees, Trees for Cities galvanizes communities and builds healthier, happier neighborhoods.

Treeconomics is a social enterprise, with a mission to highlight the benefits of trees and woodlands. Treeconomics develops projects with landowners, communities, academics and other stakeholders to quantify and value trees, green infrastructure and natural capital. Together we deliver sustainable urban forest management plans, projects and consultancy that aim to improve our environment.

Citation

Volunteer Perspectives

Lizzie Pace

As a mature student joining the arboriculture and horticulture industries, I wanted to get involved in the Ealing i-Tree survey to grow my skills, knowledge, understanding and contacts. It posed a challenge that our first plot was located in the centre of a shooting range, and took a few persuasive conversations to gain access, but once we were in, we adventured across the shooting range in a golf buggy. This was in contrast to accessing plots within residents' gardens, most of whom were interested and supportive of the project. The Project Manager gave me more training and support than I'd expected. Volunteering on this project was a valuable and positive learning experience and I'm now delighted to be working with Trees for Cities as their Urban Forest Coordinator.

Kamall Anderson

Having just completed a diploma from Capel Manor in Countryside Management I was of course enthralled when I read about the i-Tree project. As an ecologist I am only too aware of the importance of trees as a habitat, as a carbon sink, and for photosynthesis as well as being important for the water and nutrient cycles. Learning how to survey trees was therefore an opportunity not to be missed. The days we had arranged to survey were scorching hot; my team worked at a cracking rate and surveyed our plots in just two days. I had a lot of fun volunteering with Trees for Cities and have learned new skills and survey techniques, which I have since applied to my coursework.

Jan Anderson

My team really enjoyed exploring our survey plots – including being granted access into the rather swish Ealing golf club, several private gardens, a lovely primary school and Perivale ancient woodland. Those contrasted with a very jolly trip to a car scrap yard where the guys were really welcoming and quite bemused at three ladies coming to check for trees! Sadly they didn't have any but we enjoyed watching them squashing and stacking old cars.

CONTENTS

Background

Benefits of Urban Trees

The urban forest comprises all the trees in the urban realm – in public and private spaces, along linear routes and waterways and in amenity areas. It contributes to green infrastructure and the wider urban ecosystem[2].

Trees in cities bring numerous benefits but incur costs to maintain. Whilst the costs are well known, the benefits can be difficult to quantify or justify. Nevertheless, a considerable and expanding body of research exists on the benefits that urban trees provide to those who live and work in our cities, to green infrastructure and to the wider urban ecosystem. The tree benefits measured in this study are summarised in fig 1.

2. (UFWACN, 2016) Doick, K.J., Davies, H.J., Handley, P., Vaz Monteiro, M., O'Brien, L., Ashwood F. (2016) Introducing England's urban forests: Definition, distribution, composition and benefits. UFWACN (Urban Forestry and Woodlands Advisory Committees (FWAC) Network), 14pp
3. Greater London Authority (2017) – 2016-based trend projections

Aims of the Study

Project Aims:

1. To create a model that effectively uses i-Tree as a tool to inform strategic urban forest management by local authorities

2. To pilot the model in Ealing for as part of Trees for Cities' strategic partnership with Ealing Council

3. To disseminate and inspire other local authorities and communities to realise and value the benefits their urban forest could provide

How Ealing Council will utilise the project findings:

1. Increase the overall tree cover of Ealing's urban forest

2. Increase biosecurity procedures and population resilience to pest and disease across all areas of Ealing's urban forest

3. Increase the contribution of Ealing's urban forest to addressing air pollution

4. Identify and investigate areas of potential plantable space, particularly in areas of high social need

5. Raise awareness of the importance of Ealing's urban forest to increase public engagement and understanding

The London Borough of Ealing

Ealing is the third largest London borough in terms of its population and is one of the most ethnically diverse communities in the country. Ealing comprises 23 wards and is located where the Thames Valley meets metropolitan London between the West End and Heathrow Airport. The quantity and quality of green space in Ealing is considered to be one of its many attractions. There are 19 major open areas in the borough (designated green belt or metropolitan open land) and a total of 9.75 km² of parks and green spaces (17% of the total borough's land). There are some 10 miles of canals in the borough as well as the rivers Brent and Crane and other smaller rivers and tributaries.

The Office of National Statistics estimated Ealing's population at 343,000 in 2015 and expects it to grow to 406,000 by 2041[3]. As Ealing becomes more densely developed and demand for housing increases, the competition for space will inevitably grow and the urban forest will become an ever more valuable resource. For Ealing to retain its leafy heritage, the Council understands the need to protect and manage the established trees in the borough, whilst continuing to plant the right trees in the right places.

Fig 3: Ealing's 23 wards

Method

This study used a three pronged data collection approach to ensure that both public and private trees are accounted for at borough and ward level, whilst also providing data exclusively for the trees actively managed by Ealing Borough Council. This section details the methods used, for further information see Appendix I or refer to the supporting project methodology document.

Borough-wide i-Tree Eco

To gather an understanding of Ealing's urban forest across both public and privately owned land, an i-Tree Eco (v6) plot-based assessment was undertaken. 215 randomly allocated plots of 0.04 ha (400 m²) were surveyed, representing 0.15% of the total survey area (of 5500ha). This equates to 1 plot every 25ha. Random plot selection ensures that trees on private land are included in the assessment. The following information was recorded for each plot:

Plot Information

Land use, ground cover, % tree cover, % shrub cover, % plantable space, % impermeable surface

Tree information

Tree species, shrub species, height (m), trunk diameter at breast height (dbh), canopy spread (m), the health and fullness of the canopy, light exposure to the crown and distance and direction to the nearest building.

This data was collected by 35 trained volunteers led by arboricultural professionals during July 2017. 220 plots were created for the project. This allowed for the eventuality that up to 20 plots may be inaccessible whilst still maintaining a statistically robust estimate of the urban forest. Five of the target 220 plots had access restrictions and were not recorded. These inaccessible plots represent less than 3% of the overall total.

Council Inventory i-Tree Eco

Ealing Council holds a wealth of data about trees they manage on Council-owned highways, parks and housing land. This methodology uses this existing database to run an i-Tree Eco v6 Full Inventory assessment. Similar to the random plot sampling method the model estimates some of the ecosystem services and structural characteristics of trees, with a focus on those owned and managed by Ealing Council.

The minimum data required by i-Tree Eco is tree species and trunk diameter, however the greater the range of data entered for each tree the more accurate the result (including height and crown spread for example). All trees in the Inventory without the minimum required data were therefore removed prior to analysis. For example, data for woodland blocks and tree groups were present in the Inventory, but these records could not be processed.

In total, 43,963 of 76,041 records were modelled (58% of the original dataset for individual trees). For a detailed description of the model calculations see Appendix 1.

Ward level i-Tree Canopy assessment of tree canopy cover

Canopy cover is the area of land covered by trees when looked at from above. It is not to be confused with leaf area, which is the total area of all the leaves which are layered throughout a tree canopy.

i-Tree Canopy uses aerial photography at random points to conduct a land cover assessment. Each point is classified to a ground cover type (e.g. tree canopy, road, water). 500 – 700 random sample points were classified for each of the 23wards, or until a standard error of <2% was reached.

Whilst the i-Tree Eco survey can only provide a borough-wide canopy figure, the i-Tree Canopy assessment provides a canopy cover figure for each ward in Ealing. The canopy assessment highlights the disparities in the extent of tree cover between wards, enabling preparation of localised canopy cover targets and comparison with other social indicators, such as health and well-being or living environment deprivation. Whilst the random sample methodology gives a good borough-wide picture of the urban forest, the canopy assessment allows inferences to be made on the function and value of trees at ward level.

London i-Tree Eco report

Throughout this report the Ealing data has been compared and contrasted with the results of the 2015 London i-Tree Eco survey[4]. For ease of reading, there is not a citation for each mention of the London study, London i-Tree Eco report or London's urban forest. Instead, the citation is given in the footnote and is also included in the bibliography section.

Data Limitations

The benefits of Ealing's trees are very valuable. However, the values presented in this study represent only a portion of the total value of the trees within Ealing. This is because i-Tree Eco does not value all of the services that trees provide; such as their roles in reducing building energy consumption and in moderating local air temperatures, in reducing noise pollution and improving health and well-being, providing wildlife habitat and, even, their ability to unite communities. The value of the ecosystem services provided in this report is therefore a conservative estimate.

Furthermore, the methodology has been devised to provide a statistically reliable representation of Ealing's urban forest in 2017. This report is only concerned with the trees (rather than shrubs) within Ealing that have a dbh >7cm. Thus this report should be used only for generalised information on the urban forest structure, function, and value. Where detailed information for a specific area (such as an individual park, street or ward) is required, further survey work should be carried out.

4. Valuing Londons Urban Forest – the London i-Tree Eco Study (Rogers et al 2015)

Results and Analysis

Key

Wooded Area
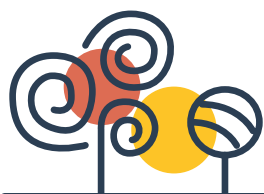
Green Spaces

Fig 4: Ealing's green spaces

Structure and Composition

Ground Cover

Ground cover in Ealing (as measured using i-Tree Eco sample survey) consisted of approximately 45% permeable 'green space', such as grass and soil. Apart from a very small percentage (0.07%) of water, the remaining ground cover is made up of non-permeable surfaces such as brick, asphalt and concrete. These 'hard' surfaces absorb heat and contribute to a general heating of the urban environment. This value is similar to that found in the London i-Tree Eco survey.

45% of Ealing's area is made up of green-space

Tree Population and Tree Density

Across Ealing there are an estimated 234,000 trees over 7 cm dbh (i-Tree Eco sample survey). The trees that make up this urban forest are situated on both public and private property. It is estimated from the i-Tree Canopy data that 43% of these trees are in public ownership and 57% in private ownership. This public/private split is identical to that calculated with i-Tree Eco for Greater London. Across the UK, US and Europe the average public private split is around 40-60 to 30-70[5].

Tree density across Ealing is 42 trees per hectare (ha). This is slightly lower than the average density of trees across London (53 trees/ha)[6] and the current UK average for

towns and cities (58 trees/ha)[7]. Roughly speaking this equates to around 0.7 trees per person in Ealing (1 tree per person was the figure calculated for the London i-Tree Eco study).

Fig 5 illustrates the tree density across Ealing's wards taken from the i-Tree Eco sample survey. Areas of high tree density include Brent Lodge and Brent Valley Park, which straddles the wards of Perivale, Hobbayne and Greenford Broadway and the areas around Horsendon Hill and Paradise Fields in North Greenford.

Fig 6 categorises tree density by ward using the i-Tree Canopy data and the average trees/ha figure from the i-Tree Eco sample survey.

5. Doick, K.J et al.
6. London i-Tree Eco Study, Rogers et al 2015
7. Britt and Johnstone 2008

The two different methods compare well and show that the wards with the highest tree density are North Greenford, Hanger Hill and Hobbayne. Those with the lowest tree density are Southall Green, Lady Margret and Southall Broadway.

Fig 6 also illustrates the proportion of public trees within each ward with data taken from the council tree inventory. Observationally, the proportion of public trees would seem fairly constant across each ward. Further investigation would be required as a significant limitation of the council inventory dataset is that it does not include any woodland trees which may be present.

Further work is required to assess available space for tree planting, and how many trees would need to be planted in the wards with lowest tree cover to increase canopy cover. Southall Broadway and Lady Margaret wards in particular may have potential to increase tree cover through increased public tree planting. See canopy cover section on page 19 for more information.
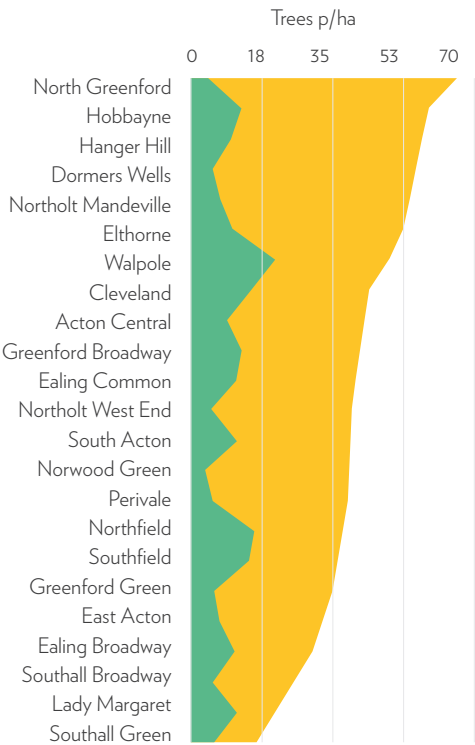

Fig 6: Tree density across Ealing Borough (yellow) and the proportion of public trees (green)
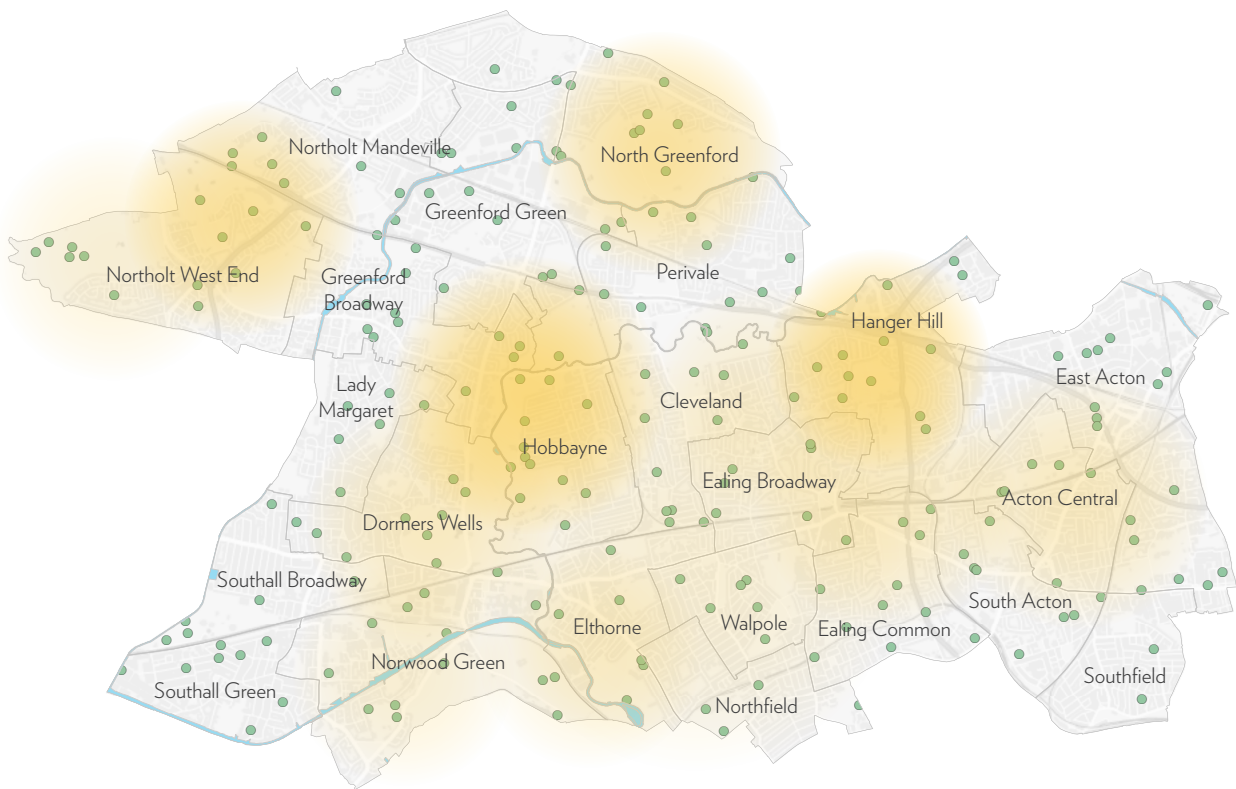
Fig 5: Tree density across Ealing – darker shades indicate higher density – i-Tree Eco plots are shown as points

Tree Species Composition

Tree species composition is an extremely important metric to consider for the sustainable management of the urban forest.

A varied species palette can not only improve the aesthetic of (and potentially define) a space or place, it will also improve the resilience of the urban forest to the combined threats of novel tree pests and diseases and of climate change. This increased resilience will of course also benefit the largest stakeholders in Ealing's urban forest: its residents.

In total, 87 tree species were recorded in the i-Tree Eco sample survey.

It is worth noting that as a sample survey the total number of species recorded is not the absolute total number species that

a. Prunus 11.7%

b. Quercus 9.2%

c. Fraxinus 7.3%

d. Crataegus 7.0%

e. Acer 6.7%

f. Tilia 6.7%

g. Malus 6.4%

h. Ulmus 6.2%

i. Populus 3.4%

j. Sambucus 3.4%

k. All Other 32.0%

Fig 7: Most common tree genera in Ealing

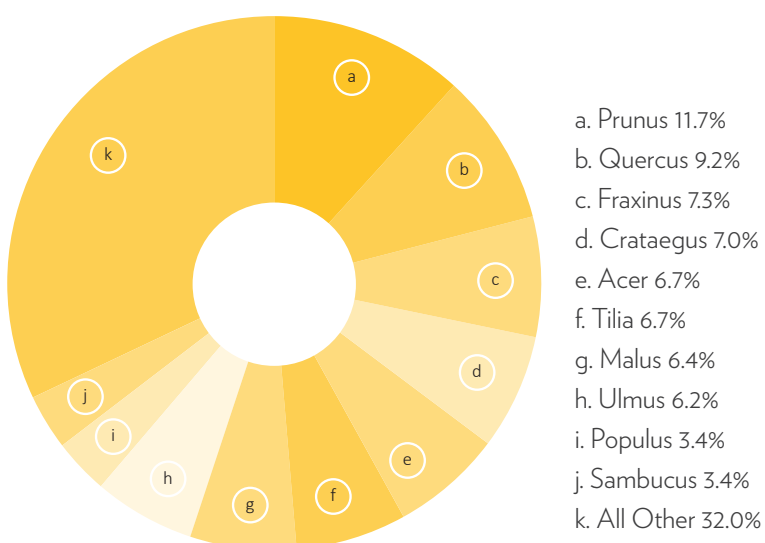would be found across Ealing. For example, within the council tree inventory there were 237 species recorded. This highlights the important contribution that public trees make to increasing tree diversity in the urban realm.

However, the sample survey provides a good estimate of the most frequently encountered species across the borough. For ease of comparison, the species composition from the council inventory and random sample survey have been simplified into generas, as illustrated in fig 7 and 8.

The three most common genera of trees across Ealing are Cherries (Prunus) with 11.7% of the tree population, Oaks (Quercus) 9.2%, and Ash (Fraxinus) 7.3%. Cherries are medium sized, growing up to 30 m, and are often deemed attractive street trees due to their spring blossom. However, Cherries are relatively short lived (<100 years) when compared with Ash and Oak trees which can grow up to 40 m and live >400 years if coppiced.

Within the council tree inventory the genera change slightly with Cherries at 15.4%, Limes (Tilia) at 13.7% and Maples (Acer) at 11.4% being the most common genera.

By way of comparison the three most common species found across Greater London were sycamore (Acer Pseudoplatanus) at 7.8% of the population, English oak (Quercus robur) at 7.3%, and silver birch (Betula pendula) at 6.2%.

Reviewing the species composition across both the public and private landholding within Ealing allows for planned public planting to complement and enhance the private tree stock, for example to ensure that there is not over-reliance in a single species or genus. Planting on the private estate is also more difficult to influence and so knowledge of what the overall tree species composition is can help in selecting or suggesting species when advice is sought.

Species composition and ward comparisons are discussed in further detail later in the diversity section.

Across Ealing, the ten most common species account for 48% of the total population.
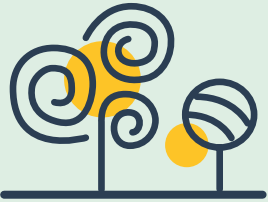
87
Tree species recorded around Ealing
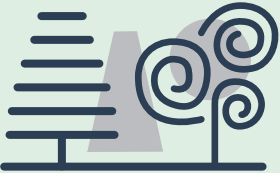
126
Tree species recorded around London

237
Council tree species recorded

a. Prunus 15.4%
b. Tilia 13.7%
c. Acer 11.4%
d. Fraxinus 6.5%
e. Sorbus 5.4%
f. Platanus 4.6%
g. Betula 4.6%
h. Malus 4.5%
i. Carpinus 3.8%
j. Aesculus 3.8%
k. All Other 26.3%

Fig 8: Most common tree genera in Council Tree Inventory

Tree Size Distribution

Size class distribution is another important factor in managing a sustainable tree population, as this will ensure that there are enough young trees to replace those older specimens that are eventually lost through old age or disease[8].

Fig 9 illustrates the size range of trees across Ealing and those from the Council tree inventory. The sizes are taken from measurements of the tree dbh.

Trees with a dbh less than 15 cm constitute 36% percent of the population (39% for the Council inventory survey and 32% for the sample survey). Across London the average was also 35% for trees below 15 cm dbh (42% for Inner London and 34% in Outer London).

The majority of trees are within the lowest size categories, with around 60% of the trees recorded having a dbh of less than 30 cm, whilst around 35% of the trees have diameters less than 15 cm.

Across both London and the London Borough of Ealing, approximately 30% of the tree population is larger than 30 cm at dbh. This compares favourably with cities and towns in other regions of England; the Trees in Towns 2 survey found that on average only 10-20% of trees have a dbh that is greater than 30 cm[9].

Large, mature trees offer unique ecological roles not offered by smaller or younger trees.

Trees in the 90 -120 cm dbh class represent the lowest percentage. To maintain a level of mature larger trees, equal to the current stocking of trees over 120 cm dbh, a proactive approach will be required to manage the trees currently in the 65 cm dbh band to ensure a suitable proportion of these trees survive and thrive to attain larger sizes.

Canopy Cover and Leaf Area

Tree canopy cover is important because it is an easy-to-understand measure that is useful in communicating messages about our urban forests with the general public, policy makers and other stakeholders. Quantifying tree canopy cover has been identified by many authors (Britt and Johnston, Escobedo, Nowak and Schwab) to be one of the first steps in the management of the urban forest.

Canopy cover is a two dimensional metric, indicating the spread of canopy cover across an area. It is not to be confused with Leaf Area Index (LAI), which is a measure of the number of layers of leaves per unit area of ground.

This study is concerned with tree canopy cover, rather than total canopy (encompassing trees, shrubs and grass). Guidance was followed to ensure tree canopy and shrub canopy were classified consistently, developed by Doick et al. (2017) for 'The Canopy Cover of England's Towns and Cities'.
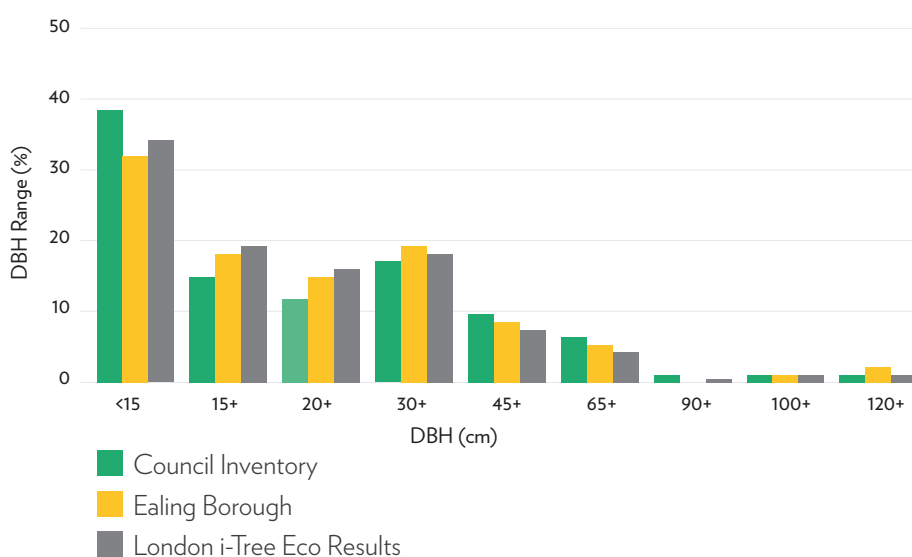
"The first step in reincorporating green infrastructure into a community's planning framework is to measure urban forest canopy and set canopy goals".
James Schwab

Fig 9: Size class distribution

8. Lindenmayer, Laurance and Franklin (2012)
9. Britt and Johnston, 2008

Canopy Cover
Ealing Wards

- 6% - 10%
- 10% - 14%
- 14% - 18%
- 18% - 22%
- 22% - 26%
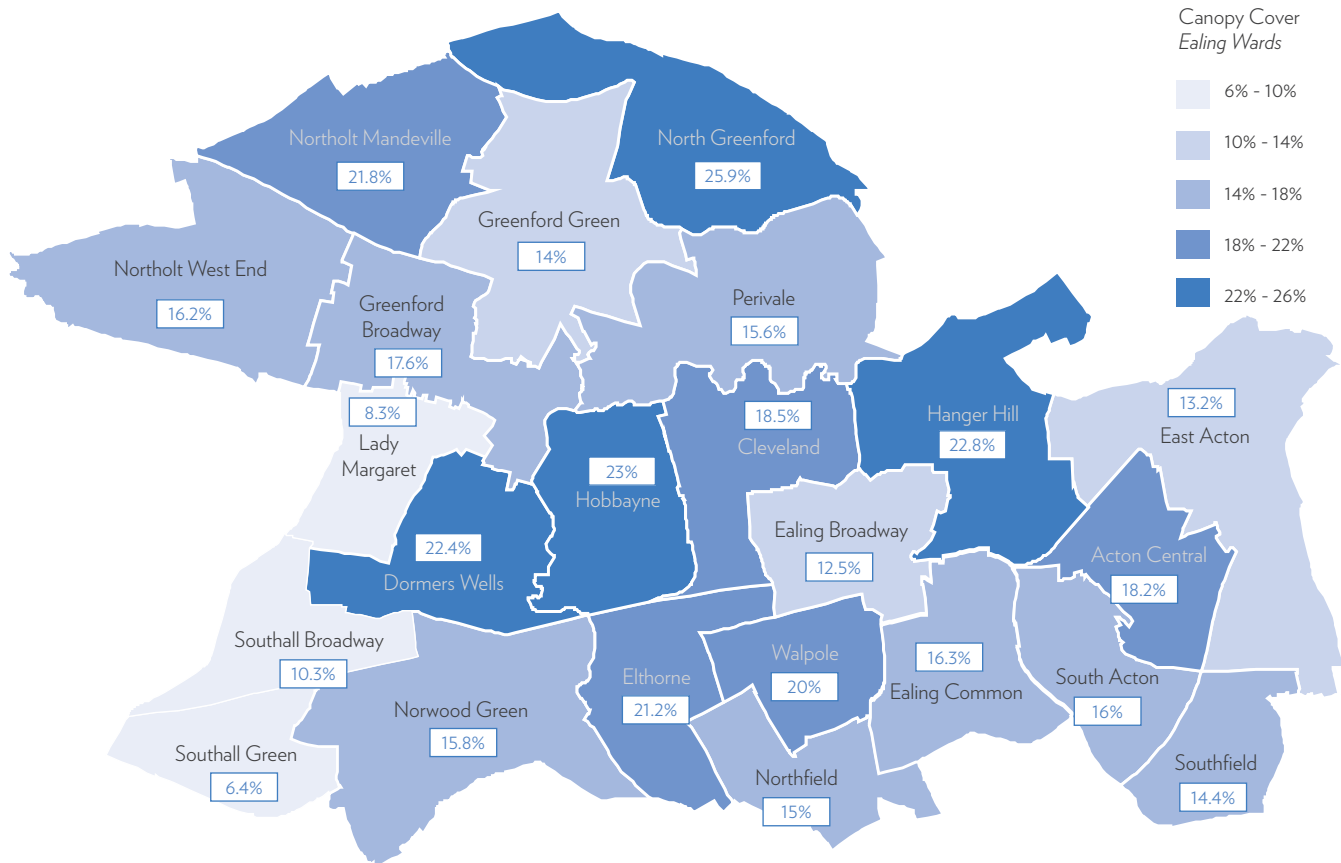
Fig 10: Canopy cover across Ealing calculated using i-Tree Canopy

Canopy cover has been calculated across Ealing at ward level (see fig 10). Fig 11 categorises canopy cover in descending order against reference lines for the London and Borough average as well as against a suggested canopy cover goal of 20%.

Average tree canopy cover across Ealing is 17%, slightly lower than the 19.5% average calculated for London[10].

It is worth noting that the three wards with lowest canopy cover (Southall Broadway, Lady Margaret and Southall Green) are also those which had the lowest tree density.
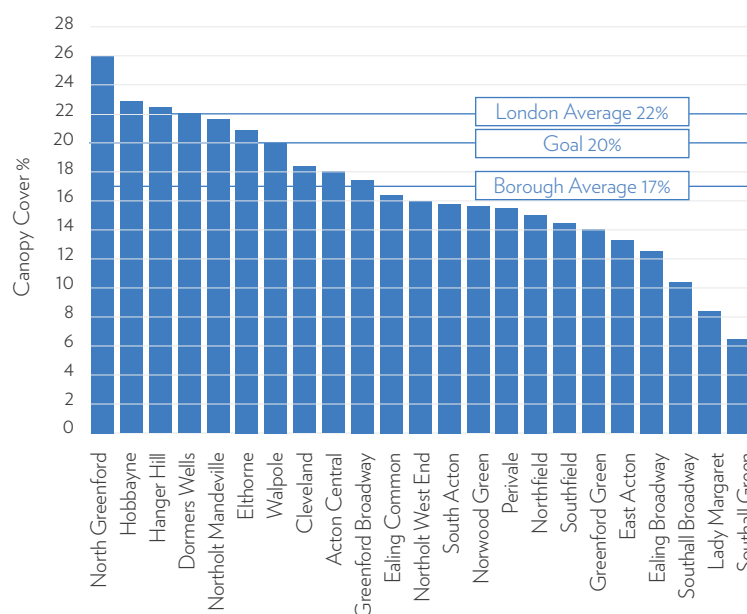
Fig 11: Canopy cover

10. Using i-Tree Eco the tree cover and shrub cover combined was 20% whilst a previous London canopy survey using aerial imagery calculated 19.5%. Available at: [https://www.london.gov.uk/sites/default/files/measuring_tree_canopy_cover_2015.pdf]

Leaf Area and Dominance

Although tree population numbers are a useful metric, greater understanding of the dominance that different species play in the delivery of benefits within the urban forest is obtained when combined with measurements on leaf area.

The main benefits derived from trees are directly linked to the amount of healthy leaf surface area that they have.

To demonstrate the dominance of a species, the gross leaf surface area of that species, combined with its abundance in the overall population, indicates its relative contribution of benefits. This is termed the dominance value (DV).

Taking into account the leaf area and relative abundance of the species i-Tree Eco calculates the DV for each species, ranking the trees in respect of their dominance for the delivery of benefits or ecosystem services.

Fig 12 illustrates the ten most dominant tree species across Ealing Borough, the council tree inventory and Greater London.

A high dominance value does not necessarily imply that these trees should form the core of any future planting strategy. Rather, it shows which species are currently delivering the most benefits based on their population and leaf area.

Percentage of Population
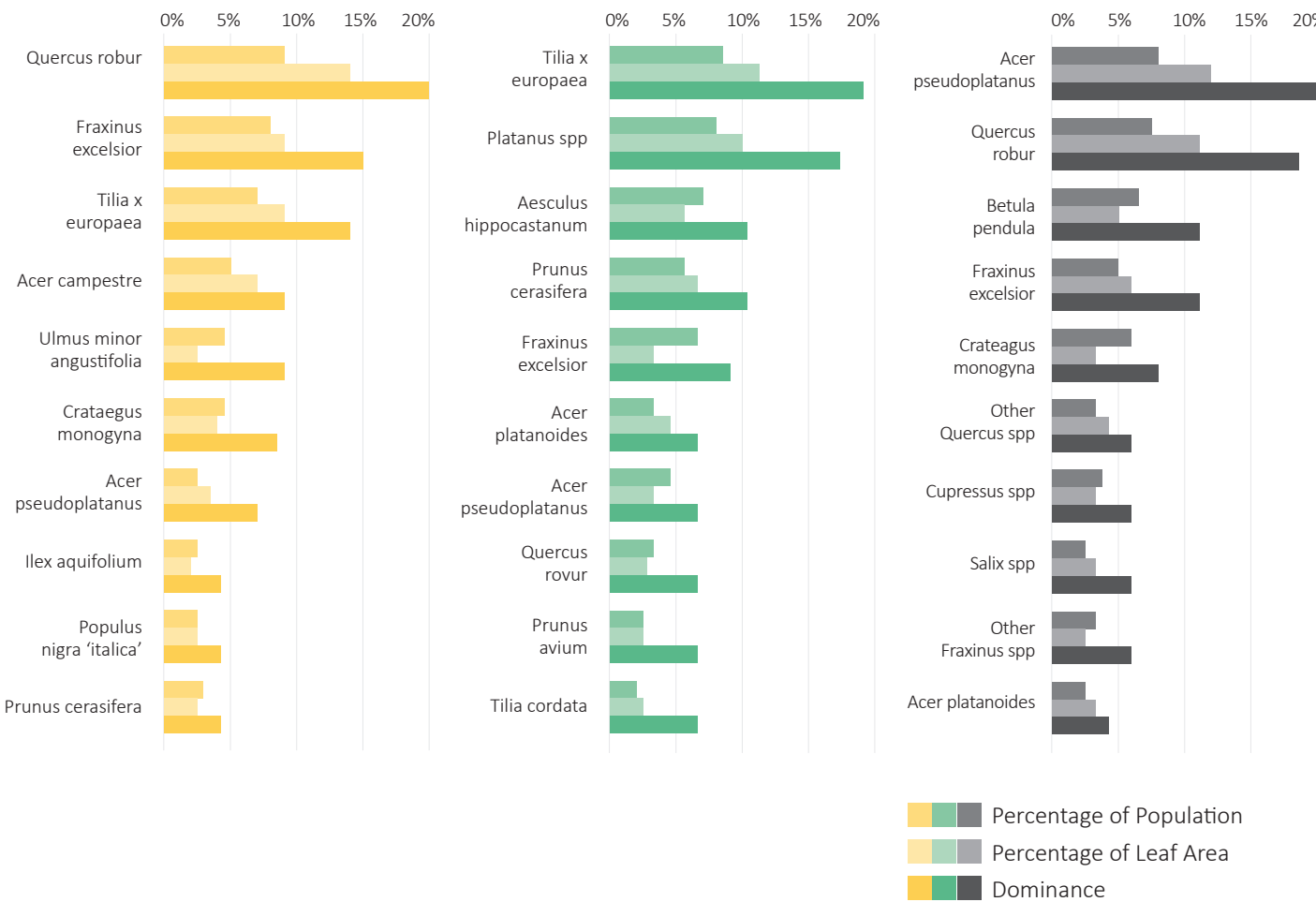Percentage of Leaf Area
Dominance

Fig 12: Ten most dominant tree species in Ealing (left), Council Tree Inventory (middle) and Greater London (right). These are the most dominant tree and as a consequence currently the most important in terms of leaf area in providing benefits
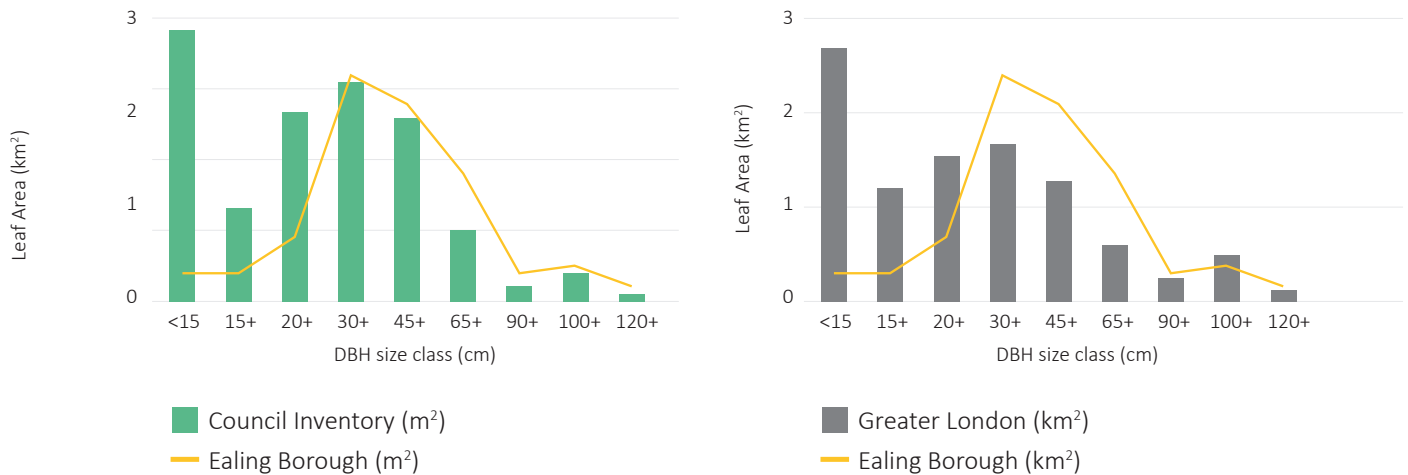
Fig 13: Leaf area (km² and m2) comparison provided by each dbh class for Ealing Council Inventory, Ealing Borough and Greater London

Across Ealing, English oak (Quercus robur), common ash (Fraxinus excelsior) and common lime (Tilia x europaea) have the largest leaf area and are also three of the most populous trees within the survey (with 21.9%, 15.7% and 13.5% of the population respectively). Although field maple (Acer campestre) and elm (Ulmus minor augustifolia) have a greater abundance than ash, they are smaller stature trees and therefore provide less associated benefits.

Across Greater London the most dominant species in the urban forest were found to be sycamore (Acer psuedoplatanus), English oak (Quercus robur) and silver birch (Betula pendula).

The species identified in the charts on the left currently dominate the urban forest structure because they are both the most abundant and have the largest leaf areas. They could therefore be considered to be the most important in terms of delivering existing benefits. However, future planting programmes should also take into account issues such as climate

change, pest and disease and the likely built form of neighbourhoods, streets and new developments.

Leaf area provided by trees for each dbh class are illustrated for Ealing Borough, Ealing's Council Tree Inventory and for Greater London in fig 13.

The pattern of leaf area by dbh from fig 13 is clear; Larger trees are under-represented in both Ealing's urban forest and potentially in the council tree inventory too[11].

Larger trees have greater functional value because they provide increased benefits to the residents of Ealing (details of functional values and the resulting benefits are discussed later).

However, Ealing has a good proportion of small and medium size trees[12] that, with proper maintenance and management, will continue to grow and thus provide a greater leaf area from a greater proportion of larger trees.

It has been estimated in previous studies that a 75 cm diameter tree can intercept ten times more air pollution, can store up to 90 times more carbon and contribute up to 100 times more leaf area than the tree canopy than a 15 cm diameter tree.

11. The council tree inventory is partial as woodland areas could not be processed
12. When compared to the Trees in Towns 2 Survey (Britt and Johnston 2008) which found that on average only 10-20% of trees within council inventories had a dbh greater than 30cm
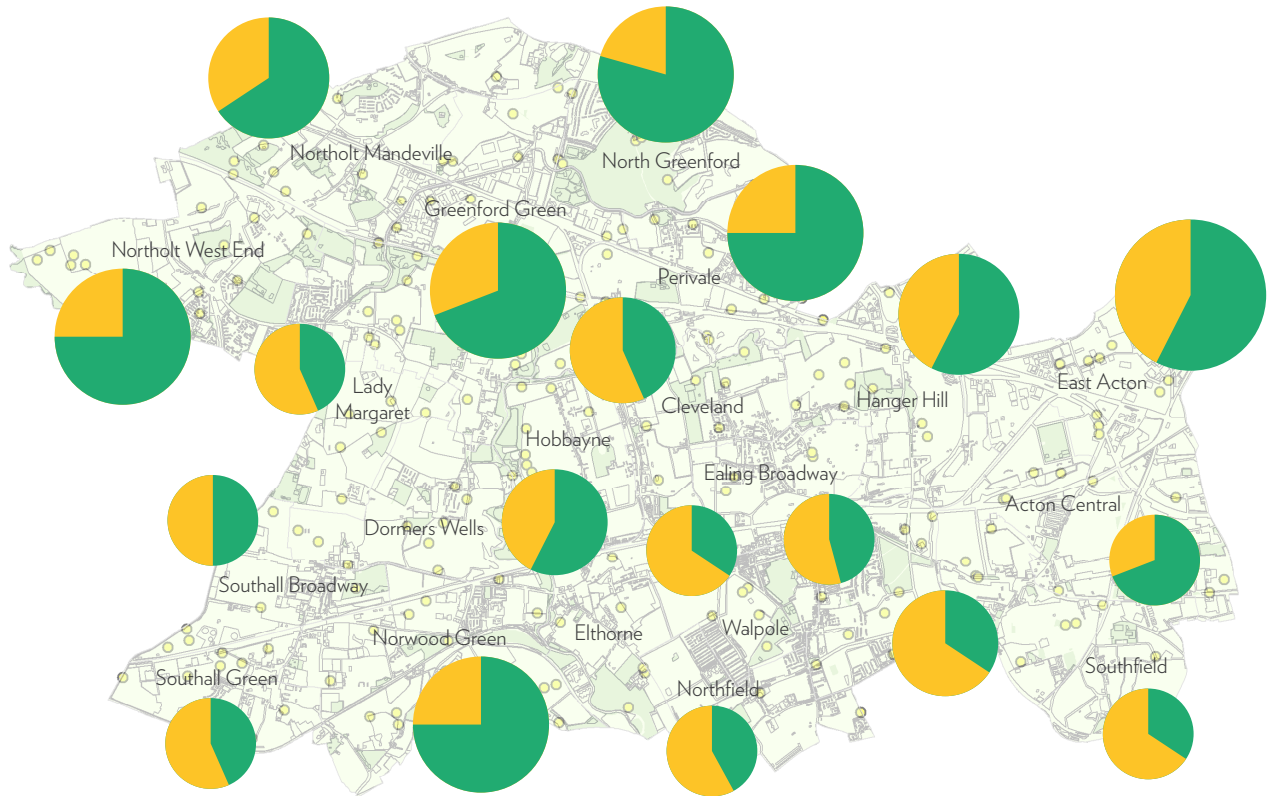
Fig 14: Proportion of tree canopy derived from public (yellow) and council (green) tree populations. Larger pie charts represent higher canopy totals
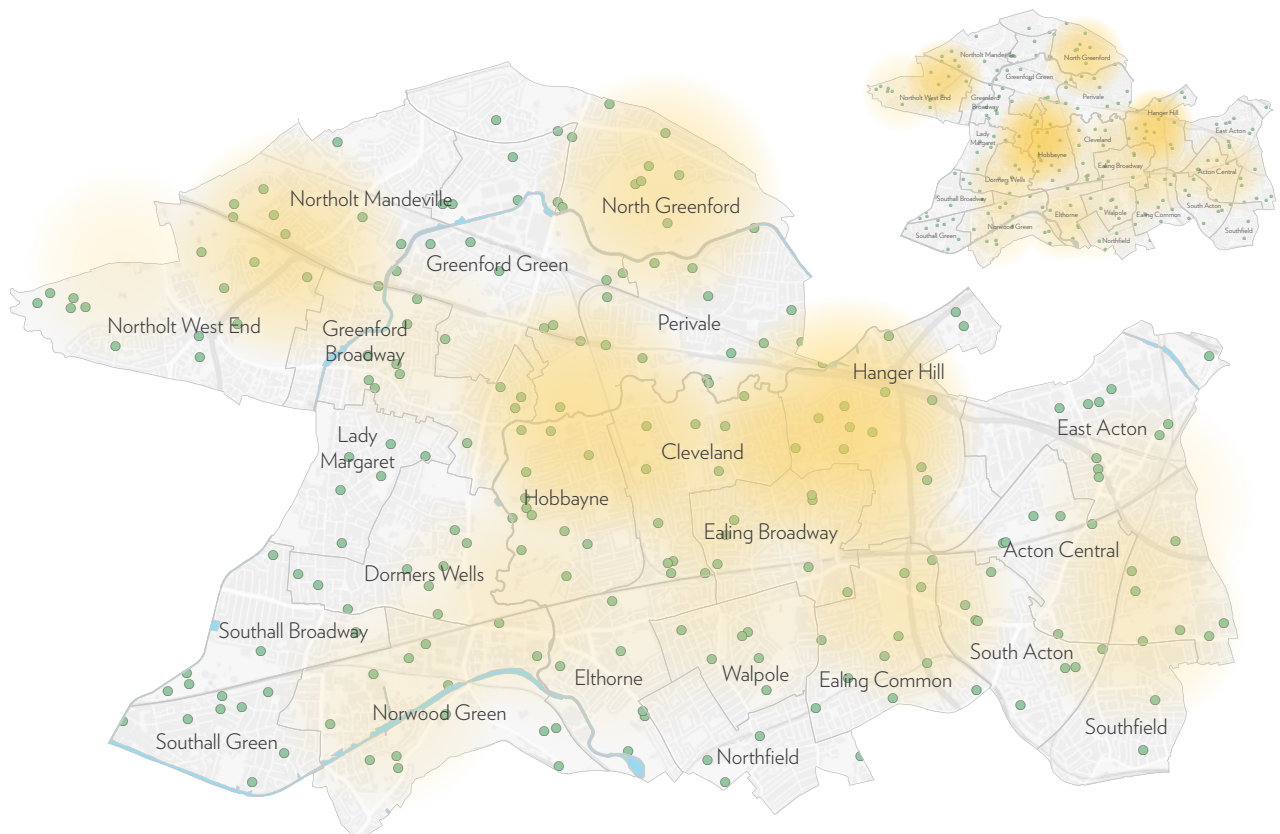

Fig 15: Tree diversity across Ealing Borough and inset tree density (i-Tree Eco sample survey) darker colours indicate greater species diversity
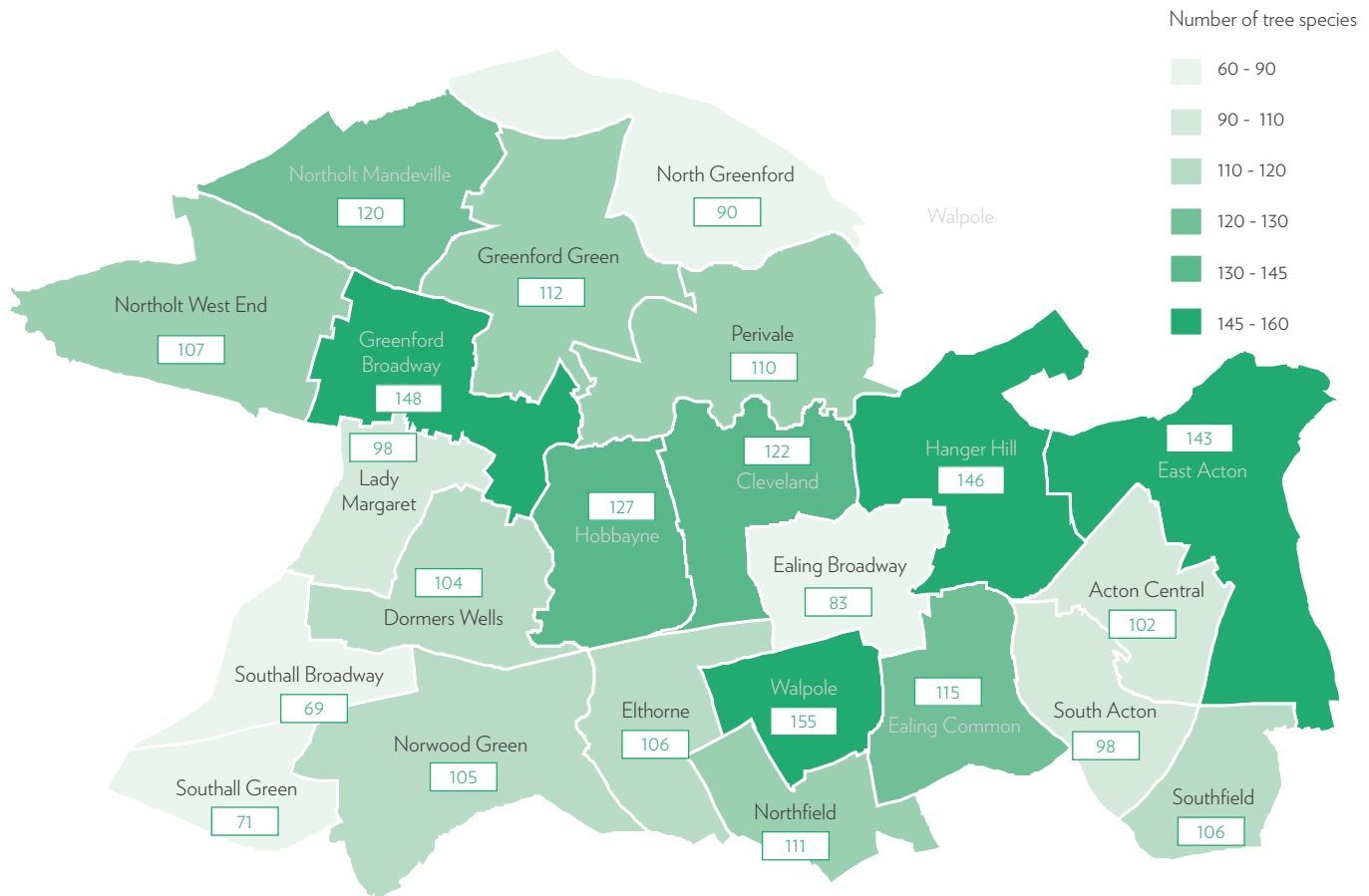
Fig 16: Tree diversity across the public tree population (council tree inventory) darker colours indicate greater species diversity

Overall, the total leaf area of Ealing's trees is approximately 30 km². This equates to over half (55%) of the total surface area of Ealing. Furthermore, the leaf area in Ealing contributes 2.7% of Greater London's total leaf area (which is 1,047km²). The Council tree inventory shows that the Council trees provide around 22.3% of Ealing's tree cover. Fig 14 illustrates the proportion of canopy on a ward by ward basis.

Tree Diversity

Diversity in the urban forest has two main components: the number of species present and the genetic diversity of the individual species present. Diversity is important as it reduces the potential impact from threats such as tree pests and diseases and climate change and increases the capacity of the tree population to deliver ecosystem services.

Fig 15 illustrates the tree diversity hotspots in Ealing which are clearly centred around the areas of highest tree density. Despite being less populated with trees, however, Hanger Hill has a more diverse tree population than North Greenford. Lady Margaret, Southall Broadway and Southall Green wards have the lowest recorded tree species diversity.

As discussed, a total of 87 species were sampled in Ealing Borough and over 200 species in the Council tree inventory.

Fig 16 illustrates the diversity of tree species across the public realm. Southall Broadway, Southall Green and Ealing Broadway wards have the lowest species diversity. To put this into context, however, even in Southall Broadway (the ward with the lowest species diversity) 69 different species were

recorded. By comparison there are only around 50 native tree species in the UK[13]).

The highest species diversity was recorded in Walpole ward (155 tree species) followed by Greenford Broadway (148 tree species) and Hanger Hill (146 species). Comparisons with other London boroughs are not yet possible due to a current lack of detailed published data.

13. https://www.woodlandtrust.org.uk/visiting-woods/trees-woods-and-wildlife/british-trees/native-trees/

Recommendations

The diversity of tree species in Ealing is generally good, although improving diversity would improve resilience to pest and disease outbreaks. Cherries are the most common species and genera across Ealing in both the Council inventory and the wider environment, but the species only has a relatively small Dominance Value. Oak, ash, planes and limes provide the bulk of the benefits (See Section: Ecosystem Services, below). However, two of these species (plane and ash) are currently at the highest risk of tree pest and disease from Ash Dieback and Plane Wilt.

Tree density in Ealing (trees/ha) is lower than the UK average and the average recorded across London. Overall canopy cover across Ealing (17.5%) is also lower than the average for London (19.6%).

There is a disproportionate ratio of smaller stature trees to larger trees across Ealing. Larger trees (over 60 cm dbh) provide a larger canopy, greater benefits and a higher return on investment.

Leaf area and canopy cover is an easy to measure metric giving a better indication of relative tree presence or dominance than just numbers of trees alone because it incorporates the area of leaves in the tree canopies, which are the driving force of many tree benefits.

Therefore it is recommended that:

1. A wider variety of tree species are planted (with due consideration to local site factors) in wards with lowest diversity to reduce the likelihood and impact from any given pest or disease outbreak.

2. Protection for existing mature and maturing trees is enhanced, together with increasing the planting of large-stature trees, (where possible) to increase canopy cover and the provision of benefits. This should be targeted to those wards with the least tree cover at present.

3. Set a canopy cover goal of increasing tree canopy cover on both public and private land. A suggested goal would be to reach 20% by 2030 as a minimum target across all wards. Part of this goal can be achieved by protecting and growing existing trees (see 2 above).

4. In order to implement and monitor these recommendations, and those that follow in further sections, it is also recommended that:

   i) Ealing Council carries out a systematic and thorough inventory of all the trees under Council ownership

   ii) A strategic urban forest master plan (with a vision for 2100) is produced setting out how these and other recommendations can be measured, targeted to the areas of greatest impact and need, and implemented. It will also set out criteria for a repeat assessment in 5-7 years to monitor progress.

5. Further investigation to establish the opportunities for, and any barriers to, the planting and establishment of trees in the lowest performing wards.

Ecosystem Services

Air Pollution Removal

Air pollution caused by human activity has become a growing – albeit changing – problem in urban areas since the beginning of the industrial revolution. Initially with the increase in population and industrialisation, and latterly with the huge increase in the numbers of vehicles on our streets, it has resulted in large quantities of pollutants being produced.

The problems caused by poor air quality are well known, ranging from human health impacts to damage to buildings and smog.

Trees make a significant contribution to improving air quality by reducing air temperature (thereby lowering ozone), directly removing pollutants from the air, absorbing them through the leaf surfaces and by intercepting particulate matter (e.g. smoke, pollen, ash and dusts). Trees can also indirectly help to reduce energy demand in buildings, resulting in fewer emissions from gas and oil fired burners, excess heat from air conditioning units and reduced demand from power plants.

As well as reducing ozone levels[14], it is well known that a number of tree species also produce the volatile organic compounds (VOCs) that can lead to ozone production in the atmosphere. The i-Tree software accounts for both production and reduction of ozone within its algorithms. Although at a site specific level some trees may cause issues, the overall effect of Ealing's trees is to reduce the production of ozone through a combination of processes such as evaporative cooling.

Total pollution removal across Ealing (i-Tree sample survey) is estimated at 33 tonnes or 0.006 t/ha/yr. This value is significant but less than the recorded average for Greater London (0.014 t/ha[15], Glasgow and Torbay, where pollution removal was recorded using i-Tree Eco as 0.050 t/ha/yr and 0.0078 t/ha/yr respectively.

Total annual amounts and pollution removal values for Ealing are shown in fig 17. Trees impacts on ozone (formed by nitrogen dioxide and sunlight) are greatest, with 24 tonnes filtered from the air every year, with an associated value of over £415,00/yr.
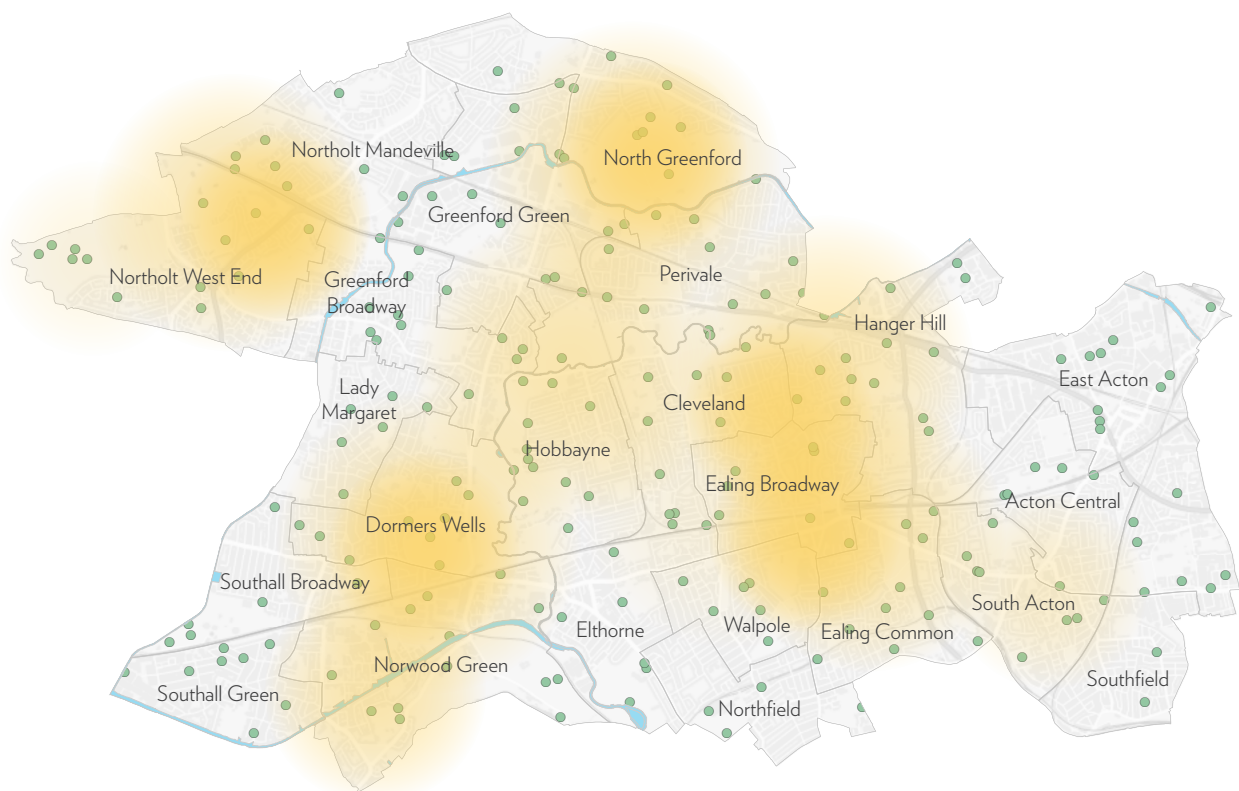
Fig 17: Air Pollution Removal across Ealing Borough (i-Tree Eco sample survey) darker colours indicate areas of greater pollution removal

14. Nowak and Dwyer (2000)
15. London i-Tree Eco Study, Rogers et al 2015
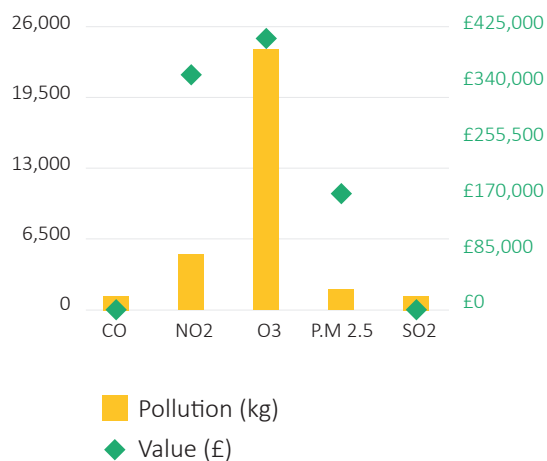
Fig 18: Value of the pollutants removed and quantity per-annum within Ealing. Valuation methods used are UK social damage cost (UKSDC) where they are available. Where there are no UK figures, the US externality cost (USEC) are used as a substitution.

Fig 18 graphically represents the value of air pollution removal by Ealing's trees, whilst fig 19 uses the Council tree inventory to categorise air pollution removal by ward. It is important to note that not all public trees are inventoried and thus these estimations are highly likely to be an underestimate of total pollution removal. However the significant proportion of trees that were inventoried still serve to illustrate trends at the ward level.

Of the public tree data investigated, the total, pollution removal by public trees equated to an estimated six tonnes every year, which contributes around 3% of the overall total for the borough (46 tonnes).

Pollution removal is greatest in Ealing Common (0.5 t/yr) followed by Walpole and Cleveland with 0.45 and 0.43 t/yr respectively. To put the figures from fig 18 into context, Ealing emit 55 tonnes of PM2.5 and 1,000 tonnes of NO2 every year from road transport alone.

Southall Green, Dormers Wells and Acton Central (all 0.1 t/yr) have the least capability with regard to air pollution removal by
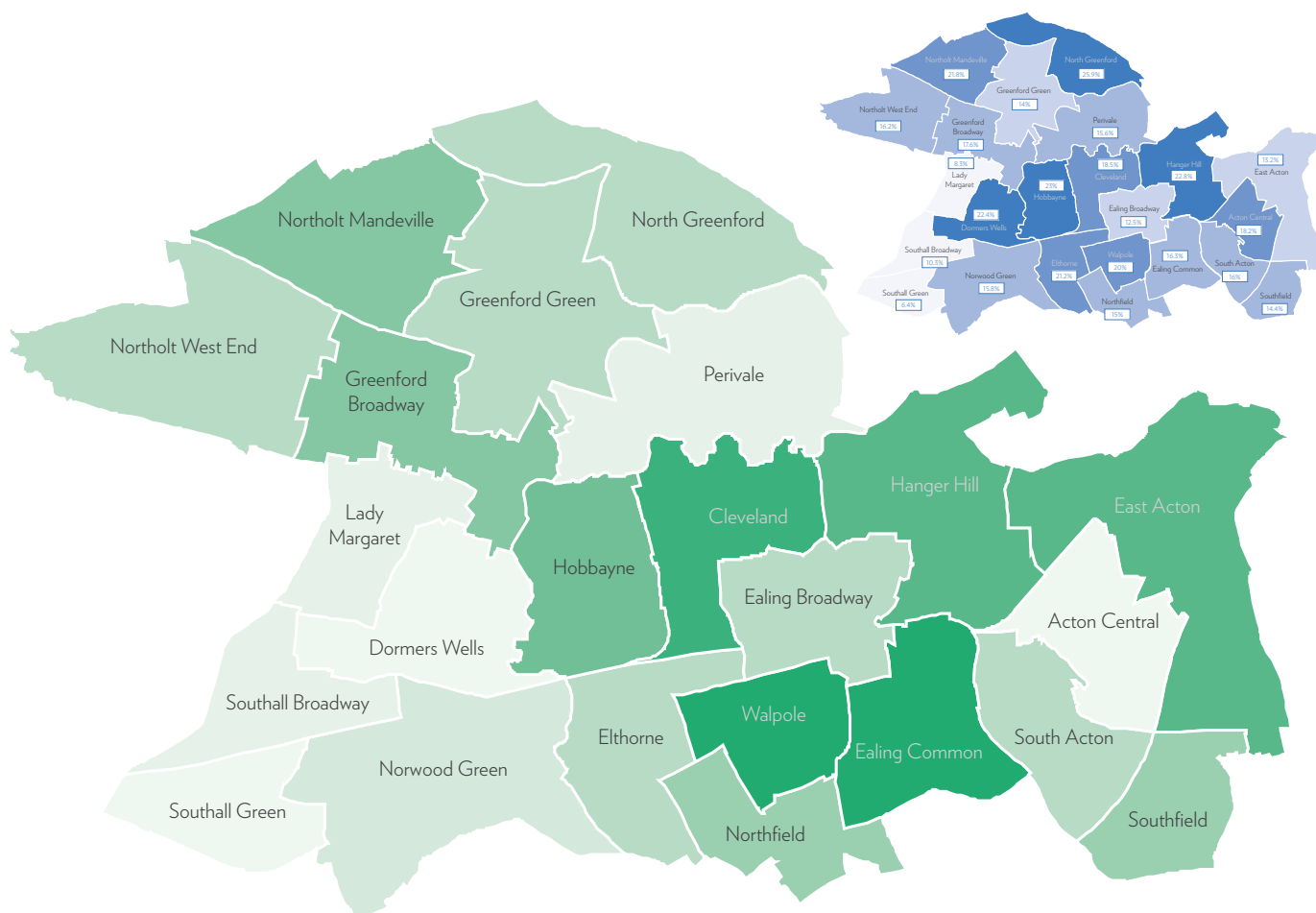
Fig 19: Pollution removal by trees across the public tree population (Council Tree Inventory) darker colours indicate greater pollution removal. Inset – Canopy cover by ward, darker colours indicate higher percentage. As air pollution removal by trees is species dependant there is not always a direct correlation with canopy cover (see dominance value graph, Fig 12)

trees. Whilst Acton Central and Dormers Wells will benefit from the air pollution removal provided by the private trees (see fig 17), Southall Green does not and so is found to be the least well performing ward along with Lady Margaret and Southall Broadway.

Greater tree cover, pollution concentrations and leaf area are the main factors influencing pollution filtration. Increasing areas of tree planting have been shown to make further improvements to air quality. Furthermore, because filtering capacity is closely linked to leaf area it is generally the trees with larger canopies that provide the most benefits.

Carbon Storage and Sequestration

Trees can help mitigate climate change by sequestering atmospheric carbon as part of the carbon cycle. Since about 50% of wood by dry weight is comprised of carbon, tree stems and roots can store carbon for decades or even centuries. Over the lifetime of a single tree, several tons of atmospheric carbon dioxide can be absorbed.

Carbon storage relates to the carbon currently held in trees tissue (roots, stem, and branches), whereas carbon sequestration is the estimated amount of carbon removed annually by trees. Net carbon sequestration can be negative if the emission of carbon from decomposition (dead trees) is greater than amount sequestered by healthy trees.

Maintaining a healthy tree population will ensure that more carbon is stored than released[16]. Utilising the timber in long term wood products will also help to reduce carbon emissions.

Trees for Cities is working in partnership with Ealing Council to engage the local community to plant new woodland habitat at Horsenden Hill in north Greenford. The trees will re-establish an area of woodland lost about 150 years ago, as well as reinstating the historic practices of using harvested timber to create woodland products. The timber will be produced when the trees are thinned and coppiced as part of routine woodland management.
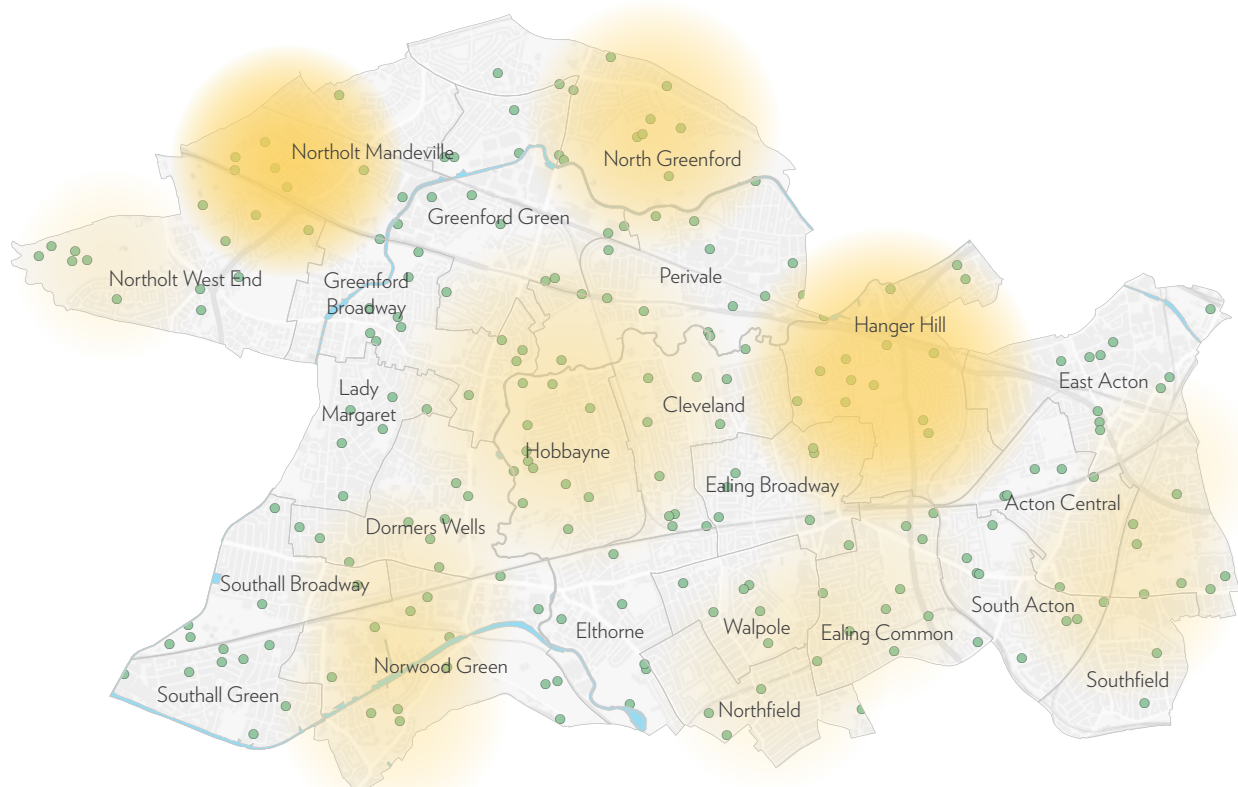
Fig 20: Carbon sequestration across Ealing Borough (i-Tree Eco sample survey) – Darker colours indicate areas of greater sequestration rates

16. Nowak et al (2002c)

An estimated 76,674 tonnes (approximately 13.9 t/ha) of carbon is stored in Ealing's trees with an estimated value of £4.9 million. Approximately 22% of this total is stored in the council trees. Across London carbon storage is around 15 t/ha, with Ealing contributing to 3% of the city total (2.37 million tonnes).

As with Greater London, oak stores the greatest amount of carbon within the urban forest (fig 21), equating to 17,675 tonnes. Together, the top ten tree species store 67% of the borough total.

The gross sequestration of Ealing's trees is about 2,246 tonnes of carbon per year (approximately 1.5 t/yr/ha). The value of this sequestered carbon is estimated at £527,000 per year. This value will increase in a non linear fashion as the trees grow and as the social cost of carbon (its value per tonne) increases. The gross amount of carbon sequestered by the urban forest in London each year is estimated at 77,200 tonnes. Therefore the London Borough of Ealing contributes around 2.9% of this total.

Across Ealing the oak, ash and lime are the most important trees in terms of carbon sequestration. With regard to the Council trees, London plane, horse chestnut and lime are currently the most significant trees in terms of carbon sequestration (see fig 22).

Trees play an important role in protecting soils, which is one of the largest terrestrial sinks of carbon. Soils are an extremely important reservoir in the carbon cycle because they contain more carbon than the atmosphere and plants combined[17].

Fig 23 shows carbon sequestration for each ward across Ealing using the Council tree inventory. Walpole, Cleveland (both 33 t/yr) and Hanger Hill (27 t/yr) are the wards where trees are sequestering the largest amounts of carbon. Southall Broadway (8 t/yr), Southall Green (9 t/yr) and Dormers Wells (10 t/yr) are the wards where carbon sequestration by trees is lowest.
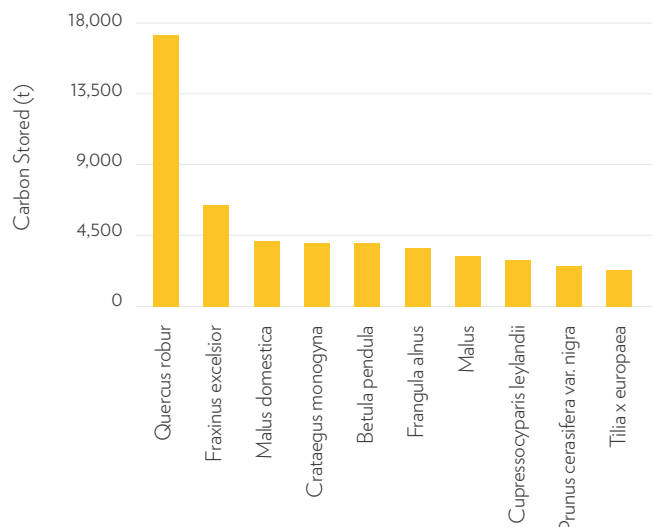
Fig 21: Ten most significant tree species across Ealing in terms of associated carbon storage
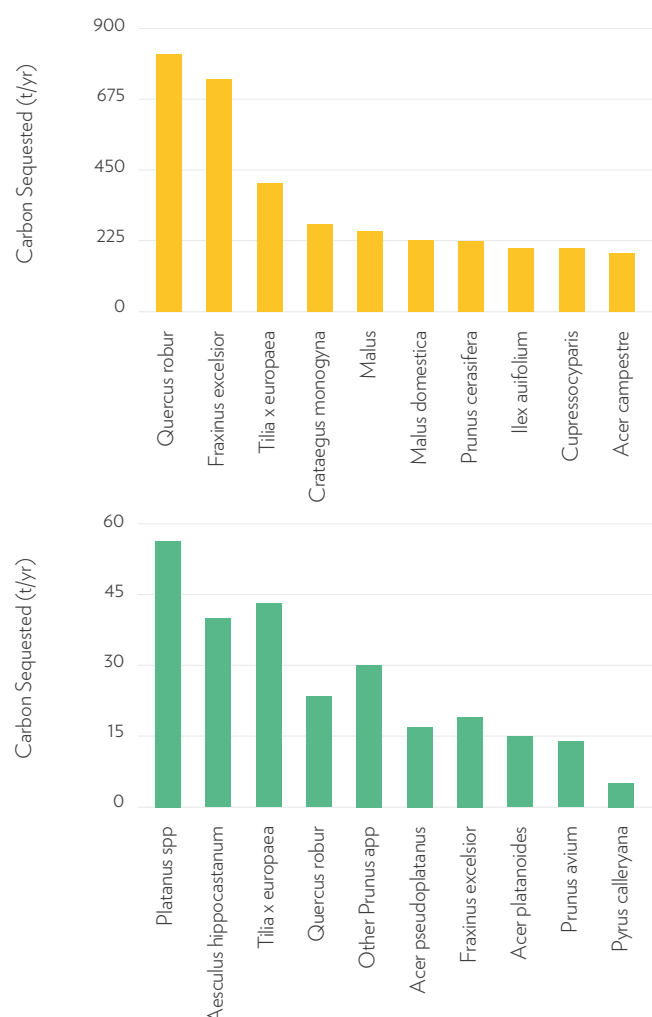
Fig 22: The carbon currently sequestered each year in Ealing's urban forest (yellow), its council trees (green)

17. Ostle et al (2009)
18. London's Environment Revealed (2011)
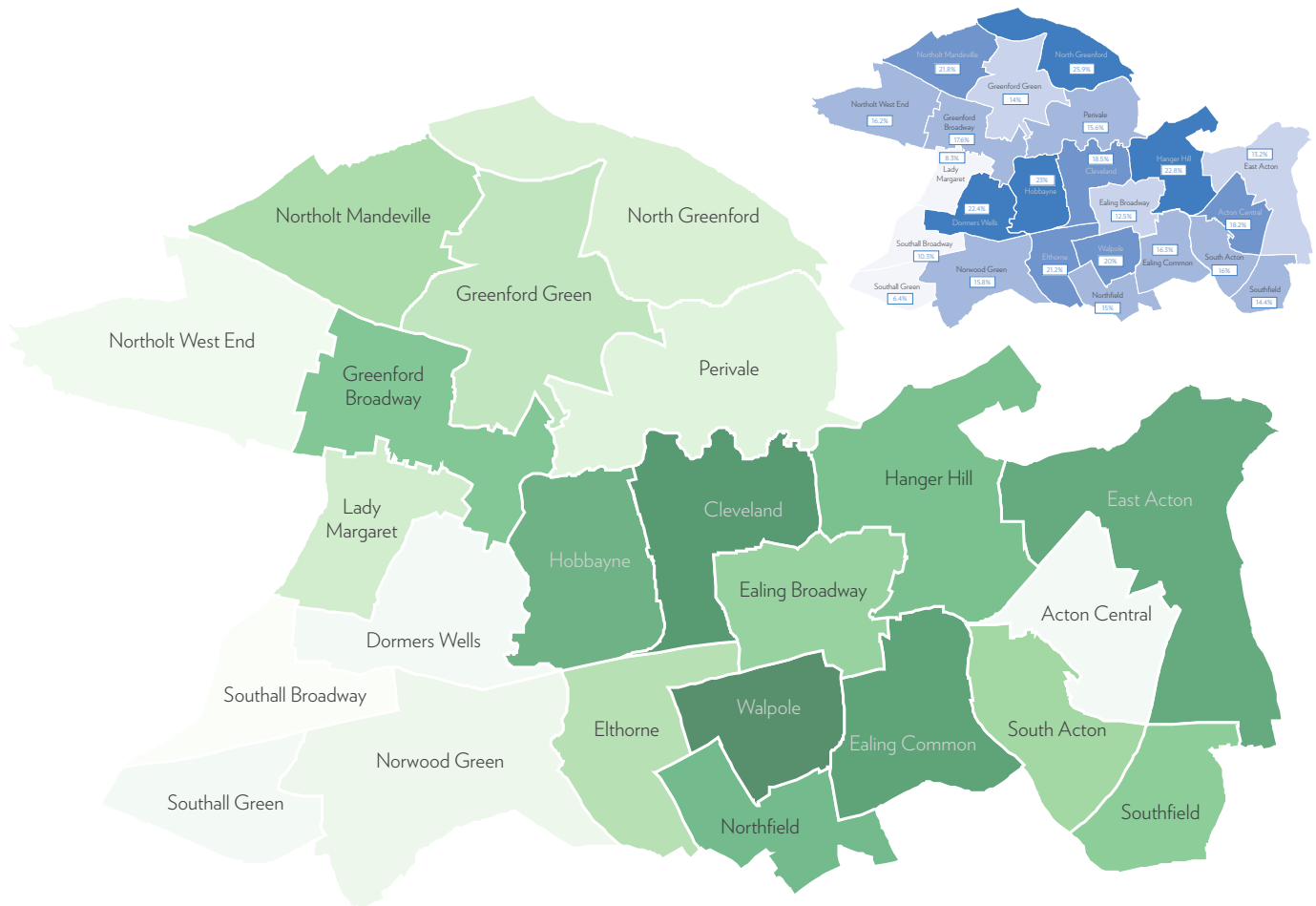
Fig 23: Carbon sequestration across the public tree population (Council Tree Inventory) – Darker colours indicate greater sequestration rates. Inset – Canopy cover by ward, darker colours indicate higher percentage

Avoided Runoff and Attenuation

Surface water flooding occurs when rainfall runs off land and buildings at such a rate that it is unable to drain away in streams, rivers, drains or sewers. It is therefore distinct from river flooding or tidal flooding where rivers or the sea breach river/sea walls and defences. It is estimated that over 80,000 homes are at high risk of surface water flooding in England and Wales[18] and that surface water flooding costs an average of £270 million per year.

Additionally, the water quality in London rivers and lakes mostly ranges from 'moderate' to 'poor' with only a handful classified as 'good'. Surface water runoff regularly causes sewer overflow and untreated sewage going straight into the Thames.[19]

Whilst the London Borough of Ealing is considered to have a generally low level of flood risk[20] there are localised areas in Ealing where there is greater risk due to multiple factors, including

proximity to rivers, problems with the drainage system, large areas of nonpermeable paved surfaces or the natural geology. Whilst local flooding is not a critical issue in Ealing, due to the Borough's topography any storm water that 'runs off' Ealing has the potential to affect neighbouring boroughs.

'Runoff' occurs in the built environment from virtually every rainfall event with streams receiving frequent discharges of polluted run-off from urban surfaces (hydro carbons, suspended solids and metals etc).

Trees have the potential to 'capture' an amount of water during rainfall events which is held in the canopies of the trees. After these rainfall events, this moisture is then re evaporated into the atmosphere. The cycle may repeat many times but water cycled in this way is diverted and thereby prevented from entering combined sewers. Some of the rainfall will also be directed down the trees network of branches and stem directly into the soil at the base of tree. This is the way in which trees attenuate or reduce run off.

19. Environment Agency Data Explorer (2017)
20. London Borough of Ealing. Local Flood Risk Management Strategy (2016)
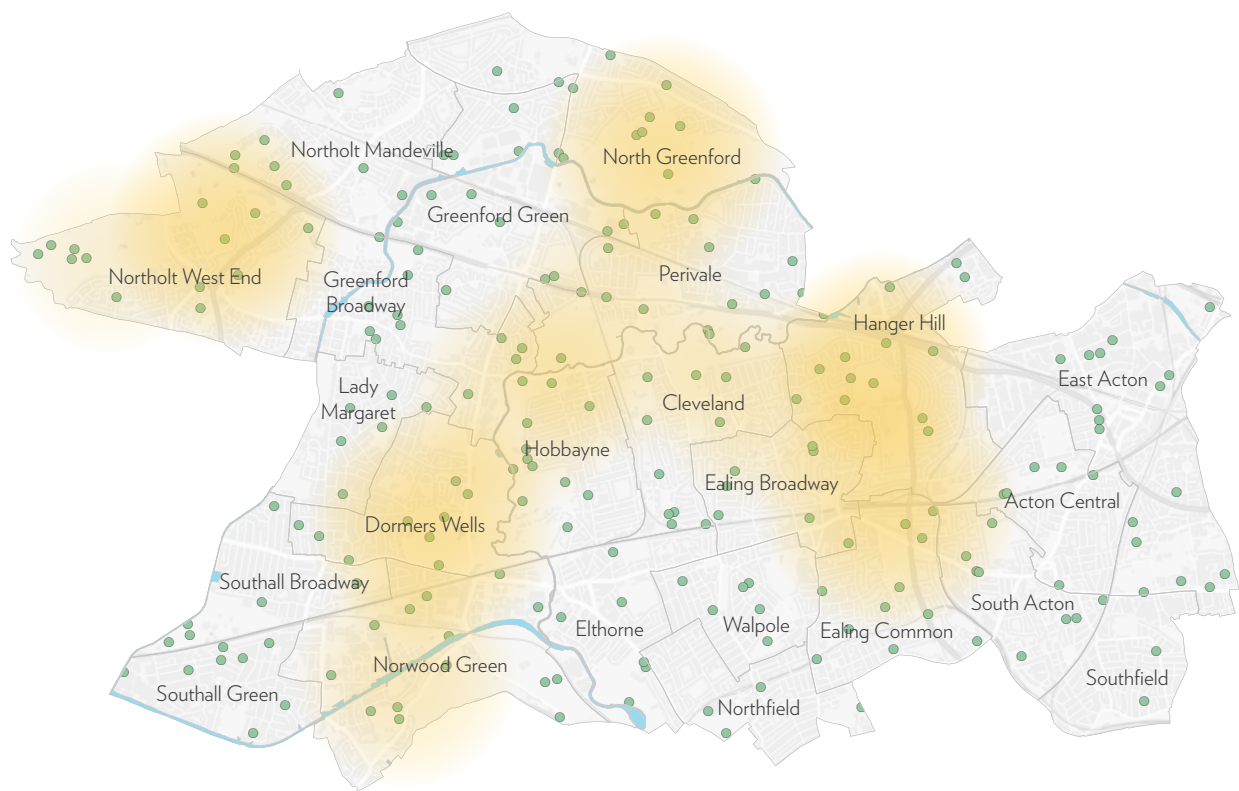
Fig 24: Avoided runoff by trees across Ealing (i-Tree Eco sample survey) – Darker colours indicate areas of greater attenuation
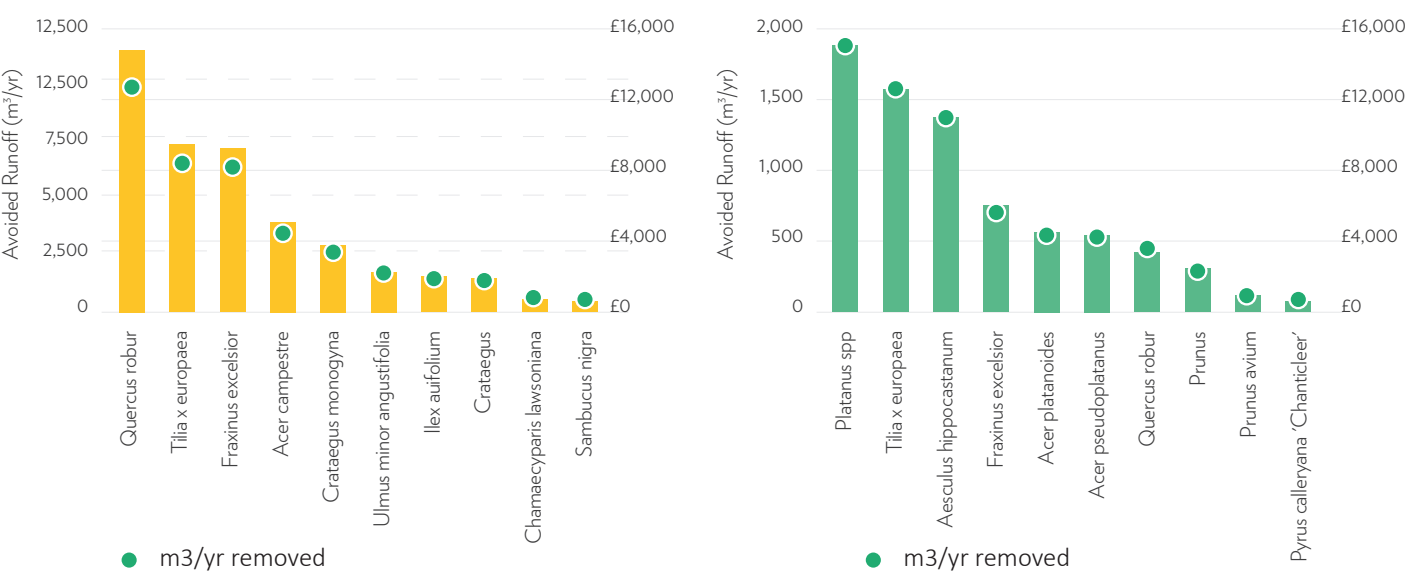
Fig 25: Comparative values for avoided runoff for the top 10 tree species by Borough (yellow) and Council trees (green)
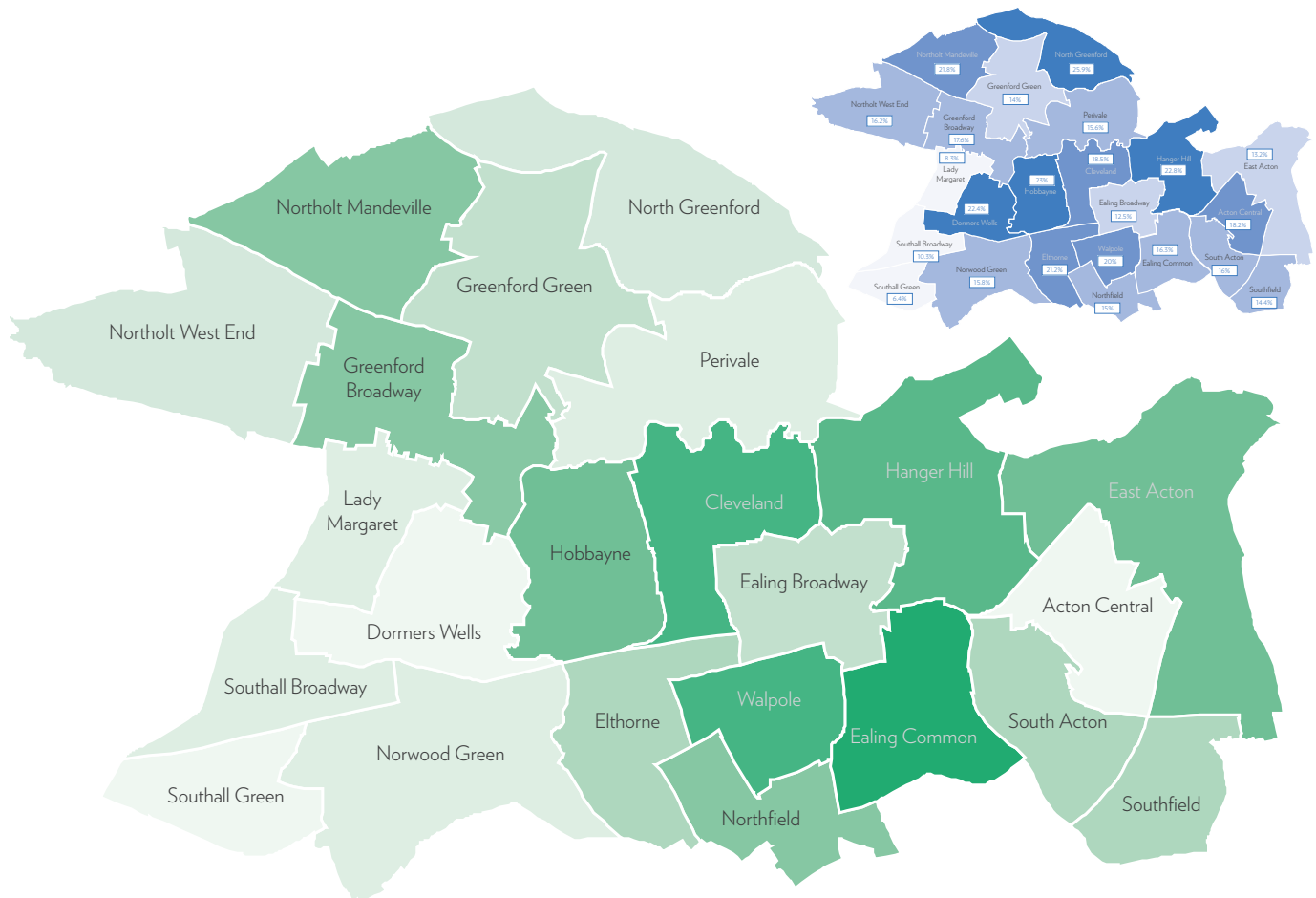
Fig 26: Avoided runoff attenuation across the public tree population (Council Tree Inventory) – Darker colours indicate higher runoff rates. Inset – Canopy cover by ward, darker colours indicate higher percentage

The 'value' of this benefit or ecosystem service is that if the water is diverted from the combined sewerage system then it does not have to be treated, meaning a very real saving in treatment costs and avoided energy emissions.

Ealing has a total tree population of approximately 234,400 trees with a leaf area of some 30km². The effect of this leaf area is to produce an avoided run off of some 74,435m³ per year. This is the equivalent of 29 Olympic-sized swimming pools. This avoided run off has a value of £113,000 every year.

Fig 24 shows how avoided runoff attenuation by trees is distributed across Ealing. As avoided runoff attenuation is dependent on tree canopy size and leaf area there is some correlation with areas of greater tree density.

Fig 25 illustrates the contribution of the top ten tree species across Ealing in reducing run off and the associated value using the avoided sewage treatment costs and avoided energy emissions.

The Council trees attenuate 13,059m³ of rainwater every year, worth nearly £20,000 per year. This contribution equates to 18% of the total avoided runoff across Ealing Borough.

Using the ward level data from the council tree inventory avoided runoff is greatest in Ealing Common (1181m³p/yr), Walpole (1015m³ p/yr) and Cleveland (958m³ p/yr).

Wards with the least value in avoided runoff were Dormers Wells (237m³ p/yr), Southall Green (254m³ p/yr) and Acton Central (293m³ p/yr).

Recommendations

Ealing's trees provide a range of benefits, however these benefits are not spread evenly across the borough. Some of Ealing's wards have low tree cover and therefore low provision of benefits. In particular, Southall Green, Southall Broadway and Lady Margaret wards are below average for a range of the measured benefits when compared to the rest of Ealing.

Strategic planning to maximise benefits from trees has to identify the needs; the trees need to be healthy and functioning efficiently, and the right species and tree locations need to be chosen to address the needs. Preferably, the impact needs to quantifiable too.

Therefore it is recommended that:

6. Local air quality and social indicators such as the indices of multiple deprivation are mapped alongside tree cover to identify spaces and places where the addition of trees could help meet local need in the lowest performing wards.

7. Areas of most need are identified and targeted to investigate for tree planting suitability. The results should also be checked by experts with local knowledge and experience as there may be 'barriers' to tree planting in the identified areas which will need to be addressed.

8. Species are selected that are appropriate to the site to maximise the benefits trees can deliver and to realise the full site potential. Tools such as i-Tree Species can be used to help decision making, but should also be informed by site appraisal. It is essential that trees are planted with some level of community engagement if planting initiatives are to succeed.

9. The development of any tree planting programmes need to be sustainable and to be co-ordinated with other local stakeholders as part of a larger sustainable urban forest masterplan for Ealing.

10. Street and greenspace tree planting is optimised for air pollution removal.

21. i-Tree species - https://www.itreetools.org/species/index.php
22. Right Trees for a Changing Climate - www.righttrees4cc.org.uk

Pests, Disease and Tree Health

Pest and Disease Impacts

Tree pests and diseases are a serious threat to urban forests. The impact of climate change is changing and extending the range of pest and disease which are likely to affect trees in the UK. This is exacerbated by the continued importation of trees from across Europe and elsewhere, particularly large landscape trees, compounded by the increasing range of packaging materials used in international trade.

Severe tree pest and disease outbreaks have occurred within living memory, with Dutch Elm Disease killing approximately 30 million elm trees in the UK throughout the late 1960s and 70s.

The potential impact of tree pests and diseases may vary according to factors such as tree health, local tree management, tree procurement policies, and the climate. In addition, tree pests and diseases may occur most frequently within a particular tree family, genus or species.

A tree population that is dominated by a few species is therefore more vulnerable to significant impact from a particular pathogen than a population which has a wider variety of tree species present. One of the prime objectives of any urban forestry management programme should be to facilitate resilience through population diversity.

The tree pest and disease analysis below only incorporates the effects from the sample plot data processed though i-Tree Eco.

The i-Tree Eco data can be interrogated to look at the effects of over 30 tree pests and diseases but only six of the most significant identified by the Council have been reviewed here.

Fig 27 shows how much of the urban forest population may be susceptible to the chosen pathogens.

Fig 28 illustrates the potential cost of replacing these trees following an outbreak by the pathogens investigated. The cost of replacing lost trees (Replacement Cost) is calculated within i-Tree Eco using the Council of Tree and Landscape Appraisers (CTLA) method adapted for the UK by Hollis (2007) and endorsed by the Royal Institute of Chartered Surveyors.

Ash Dieback poses a threat to 7% of the tree population in Ealing - a loss of trees valued at £26.8 million pounds.

Fig 27: Potential tree pest and disease susceptibility
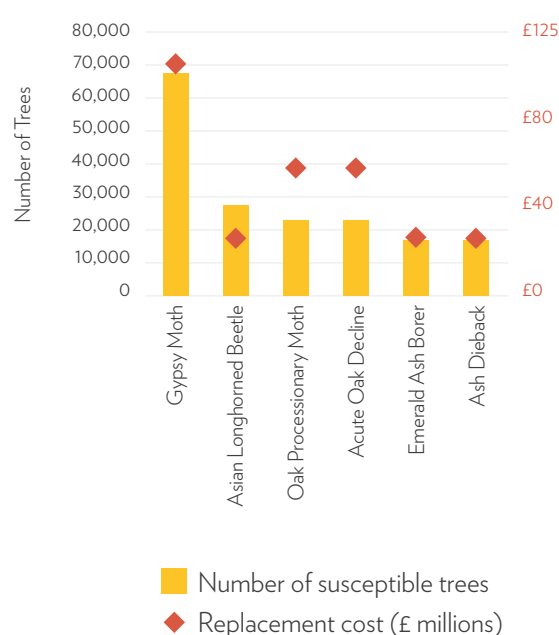
Fig 28: Potential tree pest and disease impacts – number of trees susceptible and their replacement costs
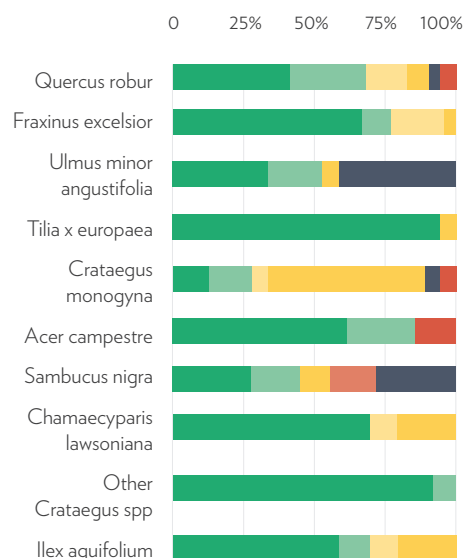
Fig 29: Overall tree health across Ealing Borough for the 10 most common species
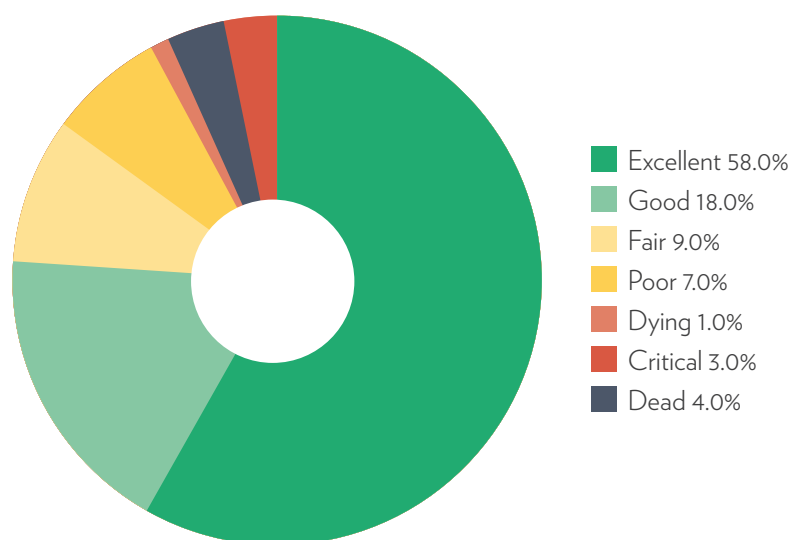
Fig 30: Overall tree condition Ealing Borough (all species)

Asian Longhorn Beetle (ALB)

Asian Longhorn Beetle is a native of SE Asia where it is a major problem. The beetle kills a variety of hardwood species, including some of those found within Ealing Borough.

To date the beetle has been found twice in the UK during inspections of incoming packaging in several ports, and a small population established in Kent in 2012 (although this was removed by the Forestry Commission and the Food and Environment Research Agency (FERA)).

As the more common families of trees contained within Ealing are preferential for the beetle, it is possible that an outbreak could affect 12% of the tree population.

It would potentially cost £26.8 million to replace the affected trees.

Emerald Ash Borer (EAB)

The EAB is a native of Asia. Once established, containment of the beetle has proved difficult. The female lays eggs in the bark of the ash tree. When hatched, the larvae feed on the tissues within the tree, creating tunnels which eventually kill the host tree.

The emerald ash borer has killed thousands of ash trees in parts of the United States and is on the march in Europe. EAB has the potential to affect 7% percent of the tree population in Ealing, which would have a replacement cost of £26.8 million.

Acute Oak Decline (AOD)

There have been episodes of 'oak decline' documented for almost 100 years; it is typically regarded as a complex disorder whereby several damaging agents interact. The outcome often results in high levels of mortality, but trees can sometimes recover. Acute Oak Decline (AOD) tends to be fast (2 – 5 years).

Conditions that make oak trees susceptible to AOD may be triggered by:

- Cycles of foliage destruction (often caused by defoliating insects and powdery mildew) which weaken the tree.

- Damage to bark cambium where phloem and cambium are destroyed (probably caused by insects and bacteria).

The most recent episode of AOD to date have occurred predominantly in the South East and Midlands. Its distribution in the UK over recent years has however slowly

intensified and spread to Wales and East Anglia, with occasional occurrences in the South West.

Once the disease has occurred, the infected trees are generally retained unless there is an imminent concern regarding human safety. Due to the close proximity of the carriageways within Ealing Borough it may be prudent to fell and destroy infected individuals to reduce infection levels and reduce the risk of the disease spreading.

Potential loss of trees from acute oak decline is 9% percent of the population. These trees would cost £59 million to replace.

Gypsy Moth

The Gypsy Moth is a defoliator of trees and shrubs which can sometimes reach outbreak numbers. Regular attacks by this pest can cause tree death. Gypsy Moth threatens 28.5% percent of the tree population in Ealing. It would potentially cost £103 million to replace the affected trees.

Ash Dieback (Hymenoscyphus fraxineus)

Hymenoscyphus fraxineus (formally Chalara fraxinea) is a vascular wilt fungus which causes the dieback and death of ash trees. Whilst thought to have been introduced to Europe in 1992, it was first discovered in the UK in a nursery in Norfolk in 2012.

Ash Dieback has had a major impact upon the ash population in several countries such as Denmark. Since being found in the UK the rate of infection has increased at a steady rate and has now been found in over 900 locations, especially in the South East[23]. Whilst initially occurring predominantly in newly planted ash populations, by the summer of 2014 infected trees were being found within established woodlands in the wider environment.

As with EAB, Ash Dieback poses a threat to 7% of the tree population in Ealing (correlating to the population of ash trees in the borough), it would potentially cost £26.8 million to replace the affected trees.

Oak Processionary Moth (OPM)

Oak Processsionary Moth (Thaumetopoea procession) was introduced into the UK in 2005. The caterpillars can affect the health of oak trees, people and animals. They feed on oak leaves and can strip trees bare leaving them vulnerable to other threats. The caterpillar can also cause human skin irritations and respiratory problems when the tiny hairs located on their bodies become airborne.

OPM has been identified in Ealing and is a threat to both the oak trees and members of the public, potentially affecting 9.2% of the tree population with a replacement cost of £59 million.

Tree Health and Condition

One of the key factors to assess the vulnerability of the resilience of an urban forest to tree pest and disease is the overall condition of the tree population. Tree condition was measured as part of the i-Tree Eco random sample survey and fig 29 shows the overall health of the trees in Ealing.

76% of the trees assessed in Ealing Borough were considered to be in either excellent or good condition exhibiting less than 5% dieback. This compares well with London where 86% of the trees were found to be in an excellent or good condition.

Of the three most common species across Ealing, English oak (Quercus robur) 67%, ash (Fraxinus excelsior) 77% and elm (Ulmus minor angustifolia) 52% were considered to be in excellent or good condition.

The small amount of dead dying and diseased trees (8%) is also acceptable as they are very important for biodiversity.

By far the least healthy of all trees encountered were the Elms (Ulmus minor augustifolia), of which over 45% were found to be either dead or dying.

23. http://silviculture.org.uk/ash-dieback-disease/

Recommendations

A whole host of pest and disease impacts could threaten the delivery of urban tree benefits across Ealing. Due to the high number of ash trees, Ash Dieback in particular poses a significant threat to o Ealing's urban forest. Although OPM is not a direct threat to the trees it affects, it is a substantial health hazard with a very real cost attached.

The data collected from this project provides an evidence base for funding and budgetary allocation, whilst also informing tree strategies and action plans that should seek to lessen the impact and improve the overall resilience of Ealing's urban forest in the short, medium and longer term.

In addition to action plans to deal with outbreaks, programmes for existing threats such as OPM need to be enhanced in light of the new data provided by this study. Furthermore, overall tree health needs to be maintained and/or improved in order to increase resilience. Species selection for new tree planting should also be informed by the latest research into novel tree pests and diseases.

It is therefore recommended that:

11. A Pest Outbreak action plan is embedded into future Ealing tree strategies and should consider tree health, how to reduce chance of new threats being introduced (biosecurity), dealing with new outbreaks (contingency planning) and where appropriate how to manage established pests and diseases to maximize benefits delivery

12. To help deliver the overarching aims, tree health has to be addressed; strategies include:

    i) Increasing ward level species diversity

    ii) Implementing an annual inspection programme of vulnerable species to maintain healthy trees

    iii) Implement biosecurity procedures and practices to minimise risk of outbreak

Replacement Cost

In addition to estimating the environmental benefits provided by trees, the i-Tree Eco model also provides a structural valuation of the trees in the urban forest. In the UK this is termed the 'Replacement Cost'. It must be stressed that the way in which this value is calculated means that it does not constitute a benefit provided by the trees. The valuation is a depreciated replacement cost, based on the Council of Tree and Landscape Appraisers (CTLA) formulae[24]. The formula allows for tree suitability in the landscape and nursery prices.

Replacement Cost is intended to provide a useful management tool, as it is able to value what it might cost to replace any or all of the trees (taking account of species suitability, depreciation and other economic considerations) should they become damaged or diseased for instance. The replacement costs for the ten most valuable tree species are shown in fig 31.

Oak is the most valuable species of tree in Ealing, on account of both its size and population, followed by ash and yew. These three species of tree account for £100,200,000 (38%) of the total replacement cost of the trees in Ealing.

Across Ealing's public trees, using the council tree inventory data, replacement cost values were highest in Walpole (£ 5,484,000) Cleveland (£4,885,000) and Northfield (£4,358,000) wards. Wards with the lowest values were Southall Broadway (£1,249,000), Dormers Wells (£1,317,000) and Southall Green (£1,477,000). Fig 32 gives the full ward breakdown.

A full list of trees with the associated replacement cost for Ealing Borough is given in Appendix 5.

The total replacement cost of all trees in Ealing currently stands at £259 million.

Fig 31: Replacement cost of the ten most valuable trees in Ealing Borough

Ward	Cost
Walpole	£5,480,000
Cleveland	£4,890,000
Northfield	£4,360,000
East Acton	£4,250,000
Ealing Common	£3,980,000
Hanger Hill	£3,860,000
Hobbayne	£3,630,000
Greenford Broadway	£3,540,000
Southfield	£3,260,000
Ealing Broadway	£3,210,000
South Acton	£2,890,000
Northolt Mandeville	£2,640,000
Elthorne	£2,460,000
Lady Margaret	£1,960,000
North Greenford	£1,940,000
Perivale	£1,930,000
Greenford Green	£1,900,000
Acton Central	£1,860,000
Norwood Green	£1,640,000
Northolt West End	£1,490,000
Southall Green	£1,480,000
Dormers Wells	£1,320,000
Southall Broadway	£1,250,000

Fig 32: Replacement Costs by Ward (Council Tree Inventory)

24. Hollis (2007)

CAVAT – The Amenity Value of Trees

Replacement cost is the cost of replacing the urban forest of Ealing should it be lost. The CTLA valuation method does not take into account the health or amenity value of trees, and is a management tool rather than a benefit valuation.

Therefore a CAVAT (Capital Asset Value for Amenity Trees) valuation was also undertaken to consider the health of trees and their public amenity value. The London Plan recommends that if trees have to be removed for development that tree replacement should be undertaken based on a valuation such as CAVAT. For the urban forest of Ealing, the estimated total public amenity asset value is £3.4 billion. This equates to around £618,400 /ha and is equivalent to 7.8% of the total CAVAT value of Londons urban forest.

Across the public estate (Council tree inventory – see fig 33) East Acton has the highest CAVAT value (£ 319,586,000) followed by Southfield (£ 201,806,000) and Walpole (£ 55,771,000) wards. The Council owned trees make up over a third of the total CAVAT value across Ealing. Totals for all wards are given in fig 33.

When calculating CAVAT both tree functionality (which can be directly related to canopy missing) and tree accessibility (the ability of the public to benefit from the amenity value of a tree) are taken into account. Further details on the CAVAT method are given in Appendix 3.

Across the whole of Ealing Borough, oak had the highest overall value, representing 9.2% of the total public amenity value of all the trees in Ealing's urban forest. The single most valuable tree encountered in the study was an English oak, estimated to have an asset value of £422,000. The top ten genera based on their CAVAT values is given in table 2.

The Ealing Borough CAVAT figures can also be broken down using the land use data collected as part of the borough wide i-Tree Eco survey. This is useful to determine where there may be a lack of, or need for, enhancement of the tree population to improve amenity.

Trees on residential land had the highest CAVAT values at approximately £2,600,000. If you extrapolate this figure out for the whole of Ealing, the CAVAT value equates to nearly £1,656 million.

25% of the amenity value of Ealing's trees currently comes from those in parks land, highlighting their importance as a public spaces and areas where trees can become large, accessible and appreciate in value.

Ward	Value
East Acton	£320,000,000
Southfield	£202,000,000
Walpole	£55,800,000
Cleveland	£55,200,000
Ealing Broadway	£46,200,000
Northfield	£43,800,000
Hobbayne	£42,100,000
Greenford Broadway	£39,700,000
Ealing Common	£39,700,000
Hanger Hill	£33,500,000
Northolt Mandeville	£32,500,000
South Acton	£27,300,000
Elthorne	£24,800,000
Greenford Green	£22,400,000
Acton Central	£21,600,000
North Greenford	£19,900,000
Perivale	£19,800,000
Lady Margaret	£17,600,000
Norwood Green	£17,300,000
Northolt West End	£14,700,000
Southall Green	£13,000,000
Dormers Wells	£10,000,000
Southall Broadway	

Fig 33: CAVAT values by ward Public trees – Council tree inventory

For the urban forest of Ealing, the estimated total public amenity asset value is £3.4 billion.

Genus	Number of Species	Estimated CAVAT value of measured trees	Total Value across Ealing (in millions)
Quercus	2	£1,281,814	£820
Fraxinus	1	£456,064	£292
Frangula	1	£418,555	£268
Tilia	3	£329,382	£211
Malus	3	£265,335	£170
Betula	3	£262,447	£168
Cupressocyparis	1	£249,469	£160
Crataegus	2	£247,066	£158
Prunus	12	£219,458	£140
Taxus	1	£196,575	£126

Table 2: % of CAVAT values by species

a. Residential 31.0%

b. Park 25.0%

c. Transportation 18.0%

d. Argriculture 12.0%

e. Multi-Family Residential 5.0%

f. Institutional 3.0%

g. Utility 2.0%

h. Golf Course 2.0%

i. Commerical/Industrial 1.0%

j. Cemetry 1.0%

Fig 34: % of CAVAT values as a percentage of land use

Policy Context

The Government's Forestry and Woodland Policy Statement[25] recognises the key role of the urban forest in engaging people with trees and woodlands on their doorstep. It notes the importance of valuing our urban trees, using tools such as i-Tree.

Urban forests can also contribute to meeting objectives 1 and 4 of Defra's strategy to 2020. These involve a cleaner, healthier environment (1) and a nation protected against floods and other hazards (4)[26].

In urban areas, linking trees to the National Policy Planning Framework (NPPF) is crucial and even though the policy only m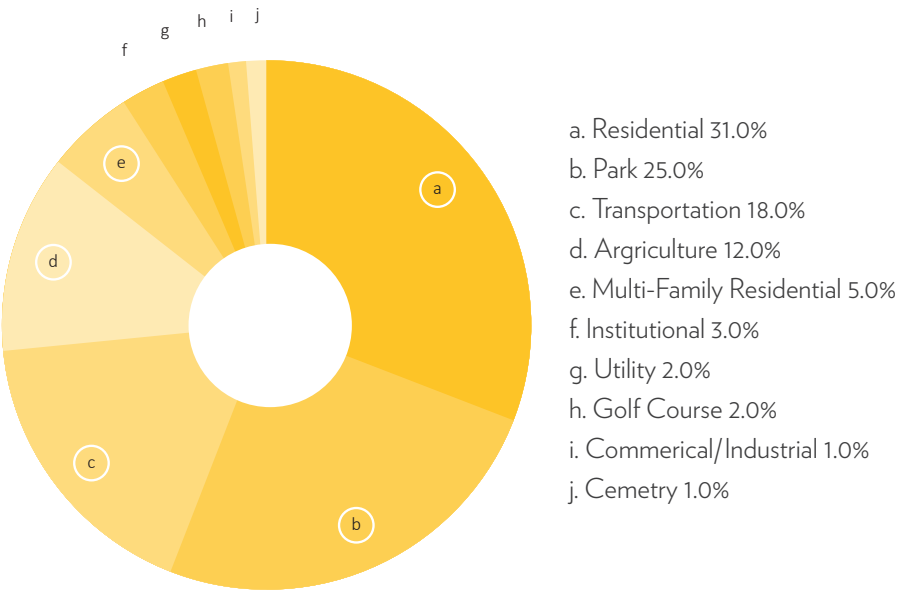entions 'trees' in the context of 'aged or veteran trees' (in paragraph 118), trees and urban tree cover are implicitly and positively linked to other key concepts – such as green infrastructure - that are emphasised and highlighted within the framework.

The contributions that trees can make to creating vibrant, liveable and sustainable places should not be overlooked. The objectives outlined in the NPPF are all dependent on the significant contribution that trees can make. In fact, of the 13 sections in the NPPF, trees are able to contribute to meeting the objectives of 11 of them[27].

At the London level, the Mayor's draft London Environment Strategy aims to make London greener. It includes a proposal to have a "major tree planting programme to ensure that London's urban forest is maintained and expanded" (Proposal 5.1.1e) and a target to increase tree canopy cover by 10% by 2050 (from 20% to 22%). The Mayor's draft London Plan also includes a trees and woodlands policy to protect existing trees and encourage the planting of new trees (Policy G7). It also suggests that London boroughs should identify opportunities for tree planting in strategic locations.

At the local (borough) level, Ealing has several policies and strategies that have links to the urban forest, these are summarised in table 3.

Policy	Section	Relevance to Ealing's Urban Forest
Ealing Council Corporate Plan (2014-2018)	Priority 3 – A Healthier Borough	The Corporate Plan is due for renewal and despite "Promote[ing] healthy communities" being a key priority of the plan, it does not mention the roles trees have to play in this. There is a substantial research to show that people are healthier and happier through regular access to leafy environments, including through reduction of stress. Conversely, when tree cover is reduced asthma rates and respiratory problems often increase as evidenced in the US where tree populations have been devastated by the Emerald ash borer. Trees thereby promote healthy communities and should be incorporated into plans to create a healthier borough.
Ealing Council Development Strategy (2026)	Chapters 4,5 and 6	Trees enhance residential and green open spaces. The development strategy recognises the benefits of street trees in the urban landscape and provides examples of where trees are incorporated into development plans for new infrastructure, such as tree-lined boulevards or segregating cycle lanes from pavements.
Ealing Council Greenspace Strategy (2012-2017)	Chapters 1 and 4	The Greenspace Strategy refers to the large number of veteran and heritage trees in the Borough. It does not include a plan for ensuring these trees remain a defining feature of the Borough's green space, however. It is vital that the next green space strategy utilises the i-Tree Eco study's results to demonstrate the value trees add to the Borough's green space.
Ealing Council Air Quality Action Plan Draft (2017-2022)	Chapter 6 – Co-Benefits of Improving Air Quality	The Air Quality Action Plan suggests increasing tree and vegetation cover to combat poor air quality. Following this study, the quantified contribution of Ealing's urban forest needs to be incorporated into this plan. There is also opportunity for further targeted study in air quality hotspot areas.
Ealing Council Tree Strategy (2013-2018)	All	The Tree Strategy great vision for the trees in Ealing and includes six key objectives and a detailed policy framework for the management of Ealing's public trees spanning 2013-2018. The project findings provide the tree section with the information required to set SMART targets at a localised and develop urban forest management plan encompassing a strategy for retaining and enhancing both public and private trees.

Table 3: Summary of policy linked to Ealings' urban forest

25. DEFRA (2013)
26. DEFRA (2016)
27. Rogers (2017) goes through each section in further detail

Conclusion

The results presented in this report and on the online dashboard provide a baseline on Ealing's urban forest structure, function and value. Ealing is the first London Borough to have such a comprehensive understanding of the state of their urban forest, offering the opportunity to draw up a coherent range of concerted actions for enhanced tree care and continued tree planting.

As anticipated at the beginning of this study, the tri-method approach has presented benefits and limitations.

Whilst more resource intensive, the random-sample plot i-Tree Eco study provides a comprehensive picture of the Borough's urban forest. This is great as it gives a detailed picture of the tree species, health, structure and function in private gardens, as well as on public land. This method is recommended for all local authorities, even where they have ample information on the structure and function of their current tree stock. Trees on private land are typically approximately equal in size and value to that under public ownership, as observed in Ealing. It is suggested that the i-Tree Eco forecast tool is used to help set targets and determine optimal delivery times for future tree planting. It is also recommended that a random-sample i-Tree Eco analysis is repeated in 5-7 years to re-assess the health of Ealing urban forest and check progress towards targets.

The council inventory i-Tree Eco method has great potential to inform the management strategy for publicly owned trees; however, the effectiveness of this method depends heavily on the completeness of the tree database. As with the random-sample i-Tree Eco method, it is advised that the i-Tree Eco forecast tool is used to help set targets and determine optimal delivery times for future tree planting. For future studies, further work should be done to ensure the database holds the minimum required information before undertaking a council inventory i-Tree Eco. As with all i-Tree Eco studies, it is also important to define the aims of the analysis so that the best use of the data and reporting can be achieved. It is recommended that this method is repeated in 5-7 years to re-assess the health of Ealing urban forest and check progress towards targets.

The i-Tree canopy results have proved very insightful for Ealing Council. Not only does a ward-level canopy cover assessment provide a strategically important baseline, it enables planning of localised canopy targets and tree strategies. Assessing canopy at ward level also allows for the findings to be presented alongside social indicators, such as the Index of Multiple Deprivation, which provides further context to the urban forest and an informed basis for targeted action. It is recommended that all local authorities conduct ward level canopy assessments every 5-7 years.

The table below summarises five key next steps for Ealing Council, and the indicators that could be used to measure progress. These measures could inform a new Urban Forest Management Plan for the whole of Ealing's Urban Forest, and help to ensure that the tree population continues to thrive and offer life affirming ecosystem services for future generations.

Recommended Next Steps for Ealing Council	Indicator	Action
Increase ward level and Borough wide Tree Canopy Cover	• % tree canopy cover per ward	Set up an Ealing Urban Forest Dashboard to illustrate ward level and Borough wide data and graphically represent progress.

Complete a business case for an urban forest master plan with a vision to 2100 that sets targets and priorities to ensure the actions are properly implemented and audited.

Conduct a multiple criteria analysis using GIS to identify areas of potential plantable space for further investigation, particularly in areas of high social need.

Carry out a systematic and thorough inventory of all trees in Council ownership. |
| Increase the climate change resilience of the tree population, including to pests and disease | • % of disease resilience (species susceptible and immune) by ward
• % Family, Genus and Species contribution to the total urban forest are within accepted guidelines | |
| Reduce the prevalence of empty plantable space | • % of plantable space which is planted | |
| Optimise street and greenspace tree planting for air pollution removal | • % of schools and other priority areas sheltered from high traffic/air pollution by vegetation | |
| Raise awareness of the importance of Ealing's urban forest to increase public engagement and understanding | • Number of stakeholders and public involved in urban forest activities
• Number of healthy trees on private land | |

Table 4: Summary of the key recommended next steps provided by this report

Appendix

Appendix 1

Notes on Methodology

i-Tree Eco is designed to use standardised field data from randomly located plots and local hourly air pollution and meteorological data to quantify forest structure and its numerous effects, including:

- Forest structure (e.g., species composition, tree health, leaf area, etc.).

- Amount of pollution removed hourly by trees, and its associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulphur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<2.5 microns and <10 microns).

- Total carbon stored and net carbon annually sequestered by trees.

- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.

- Potential impact of infestations by pests, such as (but not limited to) Asian Longhorned beetle, Emerald Ash Borer, Gypsy Moth, and Ash Dieback.

In the field, 0.04 hectare plots were randomly distributed. All field data was collected during the leaf-on season to properly assess tree canopies. Within each plot, data collection includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback.

To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data.

Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations . To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O_2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of trees account for decomposition[28].

Recent updates (2011) to air quality modelling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulphur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models[29]. As the removal of

carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature[30][31] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50% resuspension rate of particles back to the atmosphere[32].

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis. The value of avoided runoff is based on estimated or user-defined local values. As the local values include the cost of treating the water as part of a combined sewage system the lower, national average externality value for the United States is utilised and converted to local currency with user-defined exchange rates.

Replacement Costs were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information[33][34].

28 Nowak, Hoehn and Crane, 2007
29. Baldocchi, Hicks and Camara, 1987 and Baldocchi, 1988
30. Bidwell and Fraser, 1972
31. Lovett, 1994
32. Zinke, 1967
33. Hollis, 2007
34. Rogers et al., 2012

Appendix 2

US externality and UK social damage costs

The i-Tree Eco model provides figures using US externality and abatement costs. Basically speaking this reflects the cost of what it would take a technology (or machine) to carry out the same function that the trees are performing, such as scrubbing the air or locking up carbon.

For the UK, however, the appropriate way to monetise the carbon sequestration benefit is to multiply the tonnes of carbon stored by the non-traded price of carbon, because this carbon is not part of the EU carbon trading scheme. The non-traded price is not based on the cost to society of emitting the carbon, but is based on the cost of not emitting the tonne of carbon elsewhere in the UK in order to remain compliant with the Climate Change Act[35].

This approach gives higher values to carbon than the approach used in the United States, reflecting the UK Government's response to the latest science, which shows that deep cuts in emissions are required to avoid the worst affects of climate change.

Official pollution values for the UK are based on the estimated social cost of the pollutant in terms of impact upon human health, damage to buildings and crops. Values were taken from the Interdepartmental Group on Costs and Benefits (IGCB) based on work by DEFRA[36]. They are a conservative estimate because they do not include damage to ecosystems; SO2 negatively impacts trees and freshwater and NOx contributes to acidification and eutrophication. For PM10s, which are the largest element of the air pollution benefit, a range of economic values is available depending on how urban (hence densely populated) the area under consideration is. We used the 'transport outer conurbation' values as a conservative best fit, given the population density data above.

For both carbon and air pollution removal, the assumption has been made that the benefit to society from a tonne of gas removed is the same as the cost of a tonne of the same gas emitted.

For a full review of the model see UFORE (2010) and Nowak et al (2010).

For UK implementation see Rogers et al. (2012).

Appendix 3

CAVAT

An amended CAVAT method was chosen to assess the trees in this study, in conjunction with the CAVAT steering group (as done with previous i-Tree Eco studies in the UK).

In calculating CAVAT the following data sets are required:

- the current Unit Value,
- Diameter at Breast Height (DBH),
- the CTI (Community Tree Index) rating, reflecting local population density,
- an assessment of accessibility,
- an assessment of overall functionality, (that is the health and completeness of the crown of the tree);
- an assessment of Safe Life Expectancy.

The current Unit Value is determined by the CAVAT steering group and is currently set at £15.88 (LTOA 2012).

DBH is taken directly from the field measurements.

The CTI rating is determined from the approved list (LTOA 2012) and is calculated on a borough by borough basis.

Accessibility, ie the ability of the public to benefit from the amenity value of a tree, was generally judged to be 100% for trees in parks, street trees and other open areas, and was generally reduced for residential areas and transportation networks to 60% (increased to 100% if the tree was on the street), to 80% on institutional land uses and to 40% on agricultural plots. A full list is given in table X1 below.

On open spaces we divided the trees into those with 100% exposure to light, and the others, which occurred in groups. On the basis that trees in open spaces are less intensively managed we applied an 80% functionality factor to all the individual trees, a 60% factor for those in small groups and a 40% factor for those in large groups. One could simply apply an overall figure for these too, but it would not then reflect how significant a proportion of the population the trees in groups are.

Safe Life Expectancy assessment was intended to be as realistic as possible, but based on existing circumstances. For full details of the method refer to LTOA (2010).

35. DECC, 2011
36. DEFRA, 2007

CAVAT Assessment

Functionality was calculated directly from the amount of canopy missing.

The particular nature of local street trees, local factors and choices could not be taken into account as part of this study. The value should reflect the reality that street trees have to be managed for safety. They are frequently crown lifted and reduced (to a greater or lesser extent) and are generally growing in conditions of greater stress than their open grown counterparts. As a result they may have a significantly reduced functionality under the CAVAT system.

Land Use	Street Tree	Accessibility %
Agriculture	Y	100
Agriculture	N	40
Cemetery	Y	*100*
Cemetery	N	80
Comm/Ind	Y	100
Comm/Ind	N	40
Golf Course	Y	100
Golf Course	N	60
Institutional	Y	100
Institutional	N	80
Multi Family Residential	Y	100
Multi Family Residential	N	80
Other	Y	100
Other	N	60
Park	Y	100
Park	N	100
Residential	Y	100
Residential	N	60
Transportation	Y	100
Transportation	N	40
Utility	Y	100
Utility	N	20
Vacant	Y	100
Vacant	N	80
Water/Wetland	Y	100
Water/Wetland	N	60

Table 5: Accessibility Figures for CAVAT

Appendix 4

Species Dominance Ranking. A species dominance ranking is calculated by combining the gross leaf surface area of that species with its abundance in the overall tree population, thus indicating its relative contribution of benefits.

A high dominance value does not necessarily imply that these trees should form the core of any future planting strategy. Rather, it shows which species are currently delivering the most benefits based on their population and leaf area.

Rank	Scientific Name	Common Name	% Population	% Leaf Area	DV
1	Quercus robur	English oak	8.70	13.30	22.00
2	Fraxinus excelsior	Ash	7.30	8.50	15.80
3	Tilia x europaea	Common lime	4.70	8.80	13.60
4	Acer campestre	Field maple	3.60	4.70	8.40
5	Ulmus minor angustifolia	Ulmus minor angustifolia	5.90	2.20	8.10
6	Crataegus monogyna	Hawthorn	4.20	3.60	7.80
7	Acer pseudoplatanus	Sycamore	2.50	3.60	6.10
8	Ilex aquifolium	Holly	2.80	1.80	4.60
9	Populus nigra 'italica'	Lombardy poplar	2.20	2.40	4.60
10	Prunus cerasifera	Cherry plum	2.80	1.70	4.50
11	Taxus baccata	English yew	1.40	3.00	4.40
12	Carpinus betulus	Hornbeam	1.10	2.70	3.80
13	Cupressus	Cypress spp	2.00	1.80	3.70
14	Sambucus nigra	Elder	3.10	0.60	3.60
15	Betula pendula	Silver birch	1.40	2.20	3.60
16	Crataegus	Hawthorn spp	2.80	0.80	3.50
17	Malus domestica	Common apple	2.50	1.00	3.50
18	Chamaecyparis lawsoniana	Lawson cypress	2.80	0.70	3.50
19	Malus	Apple spp	2.50	0.60	3.10
20	Aesculus hippocastanum	Horse chestnut	0.60	2.50	3.10
21	Tilia cordata	Small leaf lime	0.80	2.10	2.90
22	Malus sylvestris	Crabapple	1.40	1.40	2.80
23	Populus tremula	Aspen	1.10	1.70	2.80
24	Salix caprea	Goat willow	0.80	1.90	2.80
25	Cupressocyparis leylandii	Leyland cypress	1.10	1.50	2.60
26	Quercus petraea	Durmast oak	0.60	2.00	2.60
27	Platanus x acerifolia	London Plane	0.60	2.00	2.60
28	Prunus x orthosepala	Prunus	1.70	0.80	2.50
29	Laurus nobilis	Bay tree	1.40	0.90	2.30
30	Prunus spinosa	Blackthorn	2.00	0.20	2.10
31	Prunus serrulata v spontanea	Japanese flowering cherry	0.80	1.20	2.00
32	Prunus avium	Sweet cherry	0.80	1.10	1.90
33	Magnolia	Magnolia spp	0.80	1.00	1.80
34	Larix decidua	European larch	0.80	0.80	1.60

Rank	Scientific Name	Common Name	% Population	% Leaf Area	DV
35	Ulmus glabra	Wych elm	0.30	1.30	1.50
36	Tilia platyphyllos	Bigleaf linden	1.10	0.30	1.50
37	Prunus cerasifera var. nigra	Ciruelo rojo	0.80	0.50	1.40
38	Salix fragilis	Crack willow	0.30	1.00	1.30
39	Liquidambar styraciflua	Sweetgum	0.60	0.70	1.30
40	Prunus domestica	Common plum	0.60	0.50	1.10
41	Prunus laurocerasus	Common cherry laurel	0.60	0.50	1.10
42	Ailanthus altissima	Tree of heaven	0.30	0.80	1.00
43	Salix alba 'tristis'	Weeping white willow	0.30	0.80	1.00
44	Cedrus libani	Cedar of lebanon	0.60	0.40	1.00
45	Corylus colurna	Turkish hazelnut	0.60	0.40	1.00
46	Alnus rubra	Red alder	0.30	0.70	0.90
47	Sorbus aucuparia	European mountain ash	0.60	0.30	0.90
48	Prunus	plum spp	0.80	0.10	0.90
49	Robinia pseudoacacia	Black locust	0.30	0.60	0.90
50	Pyrus calleryana	Callery pear	0.60	0.30	0.90
51	Tsuga heterophylla	Western hemlock	0.30	0.60	0.90
52	Sorbus aria	Whitebeam	0.60	0.30	0.80
53	Ficus carica	Common fig	0.60	0.30	0.80
54	Betula papyrifera	Paper birch	0.60	0.30	0.80
55	Acer platanoides	Norway maple	0.30	0.50	0.80
56	Salix alba	White willow	0.30	0.50	0.80
57	Salix x sepulcralis Simonkai	Weeping willow	0.30	0.50	0.80
58	Alnus glutinosa	European alder	0.60	0.20	0.70
59	Alnus serrulata	Hazel alder	0.60	0.10	0.60
60	Cordyline	cordyline spp	0.60	0.10	0.60
61	Platanus spp	Plane tree	0.30	0.30	0.60
62	Sorbus sargentiana	Sargent's rowan	0.30	0.20	0.50
63	Alnus incana	Grey alder	0.30	0.20	0.50
64	Corylus avellana	Hazel	0.30	0.20	0.50
65	Pinus sylvestris	Scots pine	0.30	0.20	0.50
66	Sorbus	mountain ash spp	0.30	0.20	0.40
67	Frangula alnus	Glossy buckthorn	0.30	0.10	0.40
68	Prunus padus	European bird cherry	0.30	0.10	0.40
69	Viburnum buddleifolium	Buddlejaleaf viburnum	0.30	0.10	0.40
70	Ligustrum vulgare	Common privet	0.30	0.10	0.40
71	Acer palmatum	Japanese maple	0.30	0.10	0.40
72	Magnolia splendens	Laurel magnolia	0.30	0.10	0.40
73	Sequoiadendron	giant sequoia spp	0.30	0.10	0.40
74	Larix leptolepis	Japanese larch	0.30	0.10	0.30
75	Lawsonia	lawsonia spp	0.30	0.10	0.30
76	Prunus yedoensis	Yoshino flowering cherry	0.30	0.10	0.30
77	Prunus lusitanica	Portugal laurel	0.30	0.10	0.30
78	Syringa vulgaris	Common lilac	0.30	0.10	0.30

Rank	Scientific Name	Common Name	% Population	% Leaf Area	DV
79	Sambucus canadensis	Common elderberry	0.30	<0.10	0.30
80	Trachycarpus fortunei	Windmill palm	0.30	<0.10	0.30
81	Ligustrum lucidum	Glossy privet	0.30	<0.10	0.30
82	Olea europaea europea	European olive	0.30	<0.10	0.30
83	Betula nigra	River birch	0.30	<0.10	0.30
84	Myrtus communis	Myrtle	0.30	<0.10	0.30
85	Yucca	yucca spp	0.30	<0.10	0.30
86	Lagerstroemia	lagerstroemia spp	0.30	<0.10	0.30
87	Acacia mellifera	Black thorn acacia	0.30	<0.10	0.30

Appendix 5

Full Species List. This is the full species list from the random sample i-Tree Eco study.

Scientific Name	Common Name	Number of Trees	Carbon Stored (mt)	Gross Seq (mt/yr)	Leaf Area (m²/Ha)	Leaf Biomass (mt)	Replacement Cost (£)
Quercus robur	English oak	20,297	17675.6	221.6	3.919	260.9	£57,569,775.00
Fraxinus excelsior	European ash	17,024	6256.3	200.3	2.504	266.4	£26,810,968.00
Ulmus minor angustifolia	Ulmus minor angustifolia	13,750	295.8	15.2	0.651	44.4	£187,841.00
Tilia x europaea	Common lime	11,131	2459.9	113.3	2.594	120.6	£12,614,276.00
Crataegus monogyna	Oneseed hawthorn	9,821	4041.1	80.5	1.057	133.0	£9,944,024.00
Acer campestre	Field maple	8,512	818.4	53.6	1.392	78.3	£2,348,997.00
Sambucus nigra	Elder	7,202	557.3	28.2	0.165	12.4	£1,510,624.00
Ilex aquifolium	Holly	6,548	567.6	55.4	0.542	72.5	£1,778,391.00
Chamaecyparis lawsoniana	Lawson cypress	6,548	323.13	22.89	0.206	51.40	£1,321,301.00
Prunus cerasifera	Cherry plum	6,548	523.3	61.9	0.492	29.9	£988,283.00
Crataegus	Hawthorn spp	6,548	142.5	16.9	0.222	8.0	£408,611.00
Malus domestica	Common apple	5,893	4335.4	62.7	0.299	25.8	£9,459,867.00
Malus	Apple spp	5,893	3215.3	72.3	0.179	15.4	£6,563,626.00
Acer pseudoplatanus	Sycamore	5,893	610.9	37.3	1.050	73.4	£2,245,446.00
Populus nigra 'italica'	Lombardy poplar	5,238	1236.8	50.8	0.696	50.2	£3,883,668.00
Cupressus	Cypress spp	4,583	884.2	25.6	0.519	81.2	£4,455,351.00
Prunus spinosa	Blackthorn	4,583	82.4	7.6	0.056	4.3	£263,285.00
Prunus x orthosepala	Prunus x orthosepala	3,929	814.8	44.0	0.249	19.3	£2,285,503.00
Taxus baccata	English yew	3,274	2148.7	47.5	0.875	137.0	£15,802,581.00
Betula pendula	Silver birch	3,274	4005.4	23.0	0.657	39.0	£12,309,781.00
Laurus nobilis	Bay tree	3,274	1148.9	49.3	0.252	18.9	£4,874,403.00
Malus sylvestris	Crabapple	3,274	300.8	30.7	0.422	36.4	£1,145,701.00
Cupressocyparis leylandii	Leyland cypress	2,619	3007.6	54.8	0.441	69.1	£10,222,066.00
Populus tremula	European aspen	2,619	1336.8	43.7	0.497	35.8	£5,751,882.00
Carpinus betulus	Hornbeam	2,619	797.5	51.5	0.796	48.0	£3,106,846.00
Tilia platyphyllos	Bigleaf linden	2,619	17.6	5.7	0.102	6.0	£163,689.00
Prunus cerasifera var. nigra	Ciruelo rojo	1,964	2844.1	47.2	0.160	12.3	£5,833,760.00

Scientific Name	Common Name	Number of Trees	Carbon Stored (mt)	Gross Seq (mt/yr)	Leaf Area (m²/Ha)	Leaf Biomass (mt)	Replacement Cost (£)
Larix decidua	European larch	1,964	1842.8	39.3	0.222	12.0	£4,586,747.00
Magnolia	Magnolia spp	1,964	782.5	50.8	0.292	19.5	£3,313,449.00
Salix caprea	Goat willow	1,964	755.4	40.5	0.563	35.7	£2,749,611.00
Tilia cordata	Greenspire linden	1,964	266.4	19.8	0.606	45.4	£1,770,183.00
Prunus avium	Sweet cherry	1,964	270.5	25.5	0.319	24.7	£824,829.00
Prunus serrulata v spontanea	Japanese flowering cherry	1,964	349.4	27.6	0.349	27.0	£790,850.00
Prunus	Cherry	1,964	87.1	6.1	0.015	1.2	£246,344.00
Aesculus hippocastanum	Horse chestnut	1,310	872.9	38.5	0.742	51.9	£2,933,122.00
Platanus x acerifolia	London plane	1,310	642.8	34.1	0.813	37.3	£2,028,994.00
Liquidambar styraciflua	Sweetgum	1,310	230.3	10.4	0.204	9.4	£1,578,092.00
Quercus petraea	Durmast oak	1,310	367.2	23.1	0.603	59.5	£1,308,685.00
Cedrus libani	Cedar of lebanon	1,310	104.2	8.0	0.125	19.6	£755,658.00
Sorbus aria	Whitebeam	1,310	210.2	18.0	0.086	6.8	£734,709.00
Cordyline	Cordyline spp	1,310	1.6	0.1	0.016	2.6	£655,866.00
Betula papyrifera	Paper birch	1,310	168.2	20.8	0.076	5.3	£481,040.00
Prunus laurocerasus	Common cherry laurel	1,310	228.4	11.4	0.145	11.2	£447,628.00
Pyrus calleryana	Callery pear	1,310	137.2	15.9	0.092	6.9	£407,690.00
Alnus serrulata	Hazel alder	1,310	129.8	6.2	0.017	1.3	£354,047.00
Prunus domestica	Common plum	1,310	112.1	14.9	0.153	11.9	£262,790.00
Corylus colurna	Turkish hazelnut	1,310	81.0	9.6	0.119	8.2	£233,608.00
Sorbus aucuparia	European mountain ash	1,310	66.1	10.1	0.101	8.0	£165,450.00
Ficus carica	Common fig	1,310	13.5	4.1	0.079	5.9	£86,627.00
Alnus glutinosa	European alder	1,310	21.9	3.1	0.053	3.8	£65,476.00
Frangula alnus	Glossy buckthorn	655	3691.5	9.1	0.043	3.2	£12,035,289.00
Magnolia splendens	Laurel magnolia	655	980.6	34.5	0.029	1.9	£3,481,686.00
Viburnum buddleifolium	Buddlejaleaf viburnum	655	329.8	11.1	0.040	3.0	£1,390,930.00
Platanus	Plane spp	655	278.2	10.0	0.090	4.2	£1,159,391.00
Salix fragilis	Crack willow	655	409.8	22.6	0.306	19.4	£1,112,668.00
Ulmus glabra	Golden wych elm	655	625.5	26.5	0.374	25.5	£1,026,390.00
Sambucus canadensis	Common elderberry	655	201.8	14.9	0.012	0.9	£888,607.00
Ailanthus altissima	Tree of heaven	655	268.3	15.3	0.223	16.7	£877,537.00
Robinia pseudoacacia	Robinia (false acacia)	655	197.7	14.7	0.179	9.6	£849,206.00
Acer platanoides	Norway maple	655	145.7	6.5	0.157	8.5	£718,319.00
Myrtus communis	Myrtle	655	226.1	10.6	0.005	0.4	£603,358.00
Salix alba 'tristis'	Weeping white willow	655	122.7	10.3	0.222	14.1	£447,540.00
Alnus rubra	Red alder	655	132.6	11.7	0.195	14.2	£447,384.00
Prunus padus	European bird cherry	655	141.2	13.2	0.042	3.3	£401,637.00
Trachycarpus fortunei	Windmill palm	655	1.0	<0.10	0.010	1.6	£347,924.00
Lagerstroemia	Lagerstroemia spp	655	202.9	6.2	0.003	0.2	£335,026.00
Sequoiadendron	Giant sequoia	655	40.3	3.9	0.026	4.1	£320,434.00
Alnus incana	Grey alder	655	102.7	4.0	0.059	4.3	£237,152.00
Yucca	Yucca spp	655	0.4	<0.10	0.005	0.8	£214,652.00
Salix x sepulcralis Simonkai	Weeping willow	655	44.9	6.3	0.150	9.5	£152,231.00
Tsuga heterophylla	Western hemlock	655	21.6	2.2	0.173	9.6	£134,251.00

Scientific Name	Common Name	Number of Trees	Carbon Stored (mt)	Gross Seq (mt/yr)	Leaf Area (m²/Ha)	Leaf Biomass (mt)	Replacement Cost (£)
Prunus yedoensis	Yoshino flowering cherry	655	73.9	7.4	0.016	1.2	£130,876.00
Prunus lusitanica	Portugal laurel	655	46.9	6.9	0.015	1.2	£103,042.00
Sorbus sargentiana	Sargent's Rowan	655	33.0	5.1	0.067	5.3	£84,792.00
Salix alba	White willow	655	29.3	4.8	0.155	9.8	£75,378.00
Corylus avellana	European filbert	655	19.8	3.9	0.058	4.1	£59,370.00
Sorbus	Mountain ash spp	655	30.7	5.0	0.050	3.9	£54,994.00
Syringa vulgaris	Common lilac	655	18.7	3.5	0.015	1.5	£52,520.00
Acer palmatum	Japanese maple	655	3.0	1.4	0.030	1.7	£49,107.00
Pinus sylvestris	Scots pine	655	6.1	1.0	0.055	5.3	£49,107.00
Acacia mellifera	Black thorn acacia	655	3.9	0.8	0.002	0.4	£47,634.00
Ligustrum vulgare	Common privet	655	25.1	4.3	0.032	2.9	£46,155.00
Lawsonia	Lawsonia spp	655	10.0	2.6	0.016	1.2	£43,314.00
Olea europaea europea	European Olive	655	1.1	0.7	0.007	0.5	£43,314.00
Ligustrum lucidum	Glossy privet	655	4.5	0.6	0.008	0.7	£35,246.00
Betula nigra	River birch	655	5.5	1.2	0.005	0.4	£30,446.00
Larix leptolepis	Japanese larch	655	8.2	1.7	0.020	1.3	£16,205.00

Appendix 6

Relative Tree Effects

The trees in Ealing provide benefits that include carbon storage and sequestration and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average carbon emissions and average family car emissions. These figures should be treated as a guideline as some are largely based on US values (see footnotes).

Leaf area is equivalent to:

- 4,096 Wembley pitches
- 55% of the total surface area of Ealing
- 34 years of tree growth is required to replace all the carbon currently stored in the trees

Carbon storage is equivalent to:

- Amount of carbon emitted in London Borough of Ealing in 22 days

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted by 60,000 cars in a year

Oxygen production is equivalent to:

- The Oxygen consumed by 14,087 people per year

Storm water alleviation is equivalent to:

- 30 Olympic-sized swimming pools

Average passenger automobile emissions per mile were based on dividing total 2002 pollutant emissions from light-duty gas vehicles (National Emission Trends http://www.epa.gov/ttn/chief/trends/index.html) divided by total miles driven in 2002 by passenger cars (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Average annual passenger automobile emissions per vehicle were based on dividing total 2002 pollutant emissions from light-duty gas vehicles by total number of passenger cars in 2002 (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Carbon dioxide emissions from automobile assumed six pounds of carbon per gallon of gasoline if energy costs of refinement and transportation are included (Graham, R.L., Wright, L.L., and Turhollow, A.F. 1992. The potential for short-rotation woody crops to reduce U.S. CO2 Emissions. Climatic Change 22:223-238).

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