THE ROYAL PARKS

HYDE PARK
TREE BENEFITS

An integrated assessment of tree benefits in Hyde Park using i-Tree Eco and Capital Asset Valuation for Amenity Trees

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Executive Summary

Hyde Park is an important green space in central London covering an area of over 142 hectares (344 acres) within the City of Westminster. The Park is joined on its western side with Kensington Gardens and almost (through the large traffic island at Hyde Park Corner) with Green Park to the south-east. The park forms an outstanding corridor of open space and cultural heritage, stretching from Kensington Palace to Whitehall.

One of the most significant elements of the park are its trees. These trees are considered the foundations of our 'urban forest'.

What is the definition of Urban Forest-? the ecosystem containing all of the trees, plants and associated animals in the urban environment, both in and around dense human settlements.

The urban forest brings a dynamic aspect to the otherwise hard city, providing a range of benefits that include flood protection, pollution filtration, carbon storage, space for recreation and habitat for wildlife.

However, in most landscapes the benefits provided by such 'natural capital' is often poorly understood. Consequently, these benefits (or ecosystem services) are often undervalued.

Economic valuation of our natural capital can help to mitigate for development, inform land use change and reduce any potential impact through planned intervention to avoid a net loss of natural capital. Such information can be used to help make better management decisions.

This report highlights the findings of a study to record the structure and composition of the trees in Hyde Park, calculate some of their functions (benefits or eco-system services) and to value the services provided by those functions.

In order to produce values for some of the benefits provided by trees a state of the art, peer reviewed software system called i-Tree Eco[1] (referred to as 'Eco' throughout the report) was used.

Highlights

The trees in Hyde Park remove a total of 2.7 tonnes of pollutants each year and store 3,900 tonnes of CO_2.

Existing trees in Hyde Park divert up to 3,600 cubic meters of storm water runoff away from the local sewer systems each year. This is worth over £5,430 annually.

The total replacement cost of all trees in the Hyde Park currently stands at, over £12,200,000.

The London plane currently dominates the tree-scape within Hyde Park, making up 37.4% of the tree population, storing 75.9% of all carbon and filtering a similar proportion of all air pollutants.

However, the London plane represent an ageing population and in order to maintain the current level of tree benefits to the Hyde Park, more trees capable of attaining a larger stature will need to be planted in future years.

The high amenity (CAVAT) value of the London plane in particular justifies the investment required to establish and maintain very large trees in the urban environment, yet equally points to the vulnerability arising when such a high proportion of value resides in a single species.

A summary of findings, including the estimated benefits of trees, is shown overleaf.

[1] i-Tree Eco is a suite of open source, peer-reviewed and continuously improved software tools. Ir was developed by the USDA Forest Service and other collaborators to help urban foresters and planners assess and manage urban tree populations and the benefits they can provide. i-Tree Eco is one of the tools in the i-Tree suite.

i-Tree Eco is designed to use complete or sample plot inventory(ies) from a study area along with other local environmental data to:

Characterise the structure of the tree population.

Quantify some of the environmental functions it performs in relation to air quality improvement, carbon dioxide reduction, and stormwater control.

Assess the value of the annual benefits derived from these functions as well as the estimated worth of each tree as it exists in the landscape.

Hyde Park Facts

Table 1:

Hyde Park Headline Figures	Baseline Facts		
Total Number of trees measured	3,174		
Tree cover	34.5 %		
Most common species	London Plane, Lime and Sweet Chestnut		
Replacement cost	£12,246,490		
Species Recorded	104		
Amounts and Values			**£/ha**
Pollution removal	2.71 tonnes	£183,454	£1,292
Carbon storage	3,872 tonnes	£800,123	£6,198
Carbon sequestration	88 tonnes	£20,028	£141
Avoided Runoff	3,584m^3	£5434	£38
Amenity Valuation (CAVAT)	£172,843,688		£1,217,209
Total Annual Benefits	£208,916		£1,471

Table 1: Headline figures.

Total Number of Trees Measured: All trees over 7cm diameter of breast height (dbh) were recorded. For further details see the methodology section.

Tree Canopy Cover: The area of ground covered by leaves when viewed from above (not to be confused Leaf area which is the total surface area of all leaves).

Replacement Cost: value based on the physical resource itself (e.g., 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 and the US externality prices where UK figures are not available; £927 per metric ton (carbon monoxide), £6,528 per metric ton (ozone), £98,907 per metric ton (nitrogen dioxide), £1,956 per metric ton (sulphur dioxide), £273,193 per metric ton (particulate matter less than 2.5 microns).

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

Capital Asset Value for Amenity Trees (CAVAT): A valuation method with a similar basis to the CTLA Trunk Formula Method, but one developed in the UK to express a tree's relative contribution to public amenity and its prominence in the urban landscape.

Data processed using iTree Eco Version 6.1.18.

12.8M VISITORS EVERY YEAR

Source https://www.royalparks.org.uk/__data/assets/pdf_file/0005/64265/FINAL-Annual-Report-and- Accounts-2015-16.PDF.

LEAF AREA OF OVER 1.8

times the total area of Hyde Park itself.

260 TONNES

of oxygen produced every year by the trees - enough for

905 people.

Annual C emissions from

1,240

single-family houses

Sulphur dioxide removal is equivalent to:

2,240 automobiles.

104 TREE SPECIES FROM 45 GENERA

Background Context

In the UK, both natural and managed habitats are under pressure. Economic austerity in the face of profound changes in public administration is unlikely to reduce the pressure on the natural environment. Every penny spent has to count and decisions are expected to be more frequently based on cost benefit analysis rather than purely on environmental grounds.

As many of the benefits provided by natural capital are not marketable, they are generally undervalued. This may lead to the wrong decisions being made about the natural environment.

Many recent Government documents have highlighted the importance of the range of benefits delivered by healthy functioning natural systems:

- The Lawton Report: Making Space for Nature (2010). This report found that too many of the benefits that derive from nature are not properly valued; and that the value of natural capital is not fully captured in the prices customers pay, in the operations of our markets or in the accounts of government or business.
- UK National Ecosystem Assessment (2011), highlighted that a healthy, properly functioning natural environment is the foundation of sustained growth, bringing benefits to communities and businesses.
- The Natural Choice: Securing the Value of Nature (2011) This white paper set out an integrated approach for creating a resilient ecological network across England, and supporting healthy, well-functioning ecosystems and ecological networks.
- The Natural Capital Committee’s third State of Natural Capital (2015) urges government to better protect our natural capital and recommends that corporations begin to take account of these natural assets.
- Our Vision for a Resilient Urban Forest (2016) stresses the importance of recognising and investing in urban trees on account of the many benefits they provide to society.

The Royal Parks charity

The Royal Parks is a charity created in March 2017 and officially launched in July 2017 to support and manage 5,000 acres of Royal parkland across London.

It looks after eight of London's largest open spaces; Hyde, The Green, Richmond, Greenwich, St James's, Bushy and The Regent's Parks, and Kensington Gardens. Royal Parks also manage other important open spaces in the capital including Grosvenor Square Garden, Brompton Cemetery, Victoria Tower Gardens, Canning Green and Poet's Corner.

In 2017, the charity took over the role of managing the parks from The Royal Parks Agency – a former executive agency of the Department for Culture, Media and Sport (DCMS), as well as fundraising and some education from the Royal Parks Foundation. The two organisations joined forces to create our charity and bring together the best of fundraising, education and park management.

The parks are owned by the Crown with their responsibility resting with the Secretary of State for Digital, Culture, Media and Sport. The Royal Parks charity manages the parks on behalf of the government.

The Royal Parks' charitable objectives are:

1. to protect, conserve, maintain and care for the Royal Parks, including their natural and designed landscapes and built environment, to a high standard consistent with their historic, horticultural, environmental and architectural importance;
2. to promote the use and enjoyment of the Royal Parks for public recreation, health and well-being including through the provision of sporting and cultural activities and events which effectively advance the objects;
3. to maintain and develop the biodiversity of the Royal Parks, including the protection of their wildlife and natural environment, together with promoting sustainability in the management and use of the Royal Parks;
4. to support the advancement of education by promoting public understanding of the history, culture, heritage and natural environment of the Royal Parks and (by way of comparison) elsewhere;
5. to promote national heritage including by hosting and facilitating ceremonies of state or of national importance within and in the vicinity of the Royal Parks.

Every year millions of Londoners and tourists visit Hyde Park, one of the capital's eight Royal Parks. Hyde Park covers 350 acres and is home to a number of famous landmarks including the Serpentine Lake, Speakers' Corner and the Diana, Princess of Wales Memorial Fountain. The Park also offers various recreational activities including open water swimming, boating, cycling, tennis and horse riding.

The current ten-year management plan focuses on the need for a strategy for sustainably managing the trees, for their ecology, conservation and heritage contributions (LUC, 2005).

A subsequent tree survey took place in 2011 which assessed all trees in the Park. The plan included data on species, location and condition along with any health and safety concerns. This was linked to a GIS baseline map and schedules which resulted in the formulation of a strategic tree management for the park (Fay and de Berker, 2011).

The tree survey considered historical data and coordinated tree management with landscape character objectives, including views and spatial definition, to form the basis for the planting conservation and tree management strategy. As part of this survey, Veteran Trees were to be ascribed careful consideration for their visual, historical and biodiversity interest.

The current management plan highlights the priority for tree management under the following guidance. "The overall structure of tree planting with succession of established and historic lines of trees, informal groups and open assemblies of parkland trees will be maintained through an ongoing planting and tree renewal programme and with purposeful siting, selection and enhanced range of species".

Royal Parks have subsequently given increased priority to the maintenance of newly planted trees to ensure successful establishment and their subsequent continuity in providing a continuous tree-scape into the future.

Background (Urban Trees and Parks)

Trees form a visual backdrop to our urban landscape. They provide a vertical element that adds colour and texture, softening an otherwise hard architectural landscape.

Urban trees are not isolated, they are interconnected within the park, the borough and the city.

London's urban forest includes trees set within parks and other open spaces, streets, private gardens, transport corridors and neglected land. The disparate character and geographic distribution of trees within the urban forest form a backcloth to city life that can easily be taken for granted. People living within the midst of the urban forest are often unaware of the many benefits gained from trees they commonly encounter.

Within the urban forest the largest concentrations of trees and shrubs tend to be found in our municipal parks. Understanding the structure, function and value of trees within urban parks can enable people to become more engaged with their environment. Without this understanding, parks are at risk of being an undervalued, invisible asset.

Trees are a fundamental part of our urban ecosystem. In addition to their intrinsic biodiversity qualities, trees provide value as functions of their size and structure, through the natural processes of photosynthesis, transpiration and growth. In this sense trees provide 'services' for the community, enhancing amenity while improving air quality and temperature control for the benefit human health and well being.

In recent years innovative 'tools' have been designed to help understand these ecosystem services, specifically to measure the contribution trees make in reducing the impacts of carbon emissions, in filtering pollutants and in regulating local climate. Moreover these tools can help to place monetary values on these ecosystem services.

One of the original urban park designers, Frederick Law Olmsted, observed that long after "the principal outlay has been made; the result may, and under good management must, for many years afterwards, be increasing in value"[2]. Yet to date in the UK, the normal basis for estimating monetary value for public parks tends to lead to them being grossly undervalued. Currently "even the largest, most spectacular park, with beautiful mature trees, well-established shrubs, paths, benches and a bandstand, is usually valued on a council's list of assets at just £1".[3]

The CABE Grey to Green report (2009) reviewed the accounting method from historic cost accounting to current value assessment. It recommends that as the current asset valuations of many UK parks do not necessarily reflect the wider values for the community, an additional account of asset value is needed.

This study used existing data, new field work measurements and the i-Tree Eco model to quantify the structure and composition of Hyde Parks trees.

i-Tree Eco was identified as the most complete tool currently available for analysing the trees in Hyde Park. i-Tree Eco provides these values at the species level and it is therefore a very useful tool and decision support to help identify, value, manage, and develop strategies concerning the trees present within Hyde Park.

The main objectives of the study were to:

1

Assess the structure, composition and distribution of key elements of Hyde Park's trees.

2

Quantify some of the benefits of Hyde Park's trees in order to raise awareness of this 'natural capital'.

3

Establish a baseline from which to monitor trends and future progress.

[2](Sutton, 1997) [3] (CABE, 2009)

Methodology

During the summers of 2013, 2014 and 2015 a trained field crew of Royal Parks staff and volunteers recorded details on all of the trees in the Hyde Park.

3,174 trees were assessed as part of this study. Information on tree species and location was recorded, as well as detailed field measurements to assess the size and condition of the trees.

The collected field measurements were processed along with local pollution and climate data using the i-Tree Eco, [4]software to provide the results contained within this report (summarised in the table below).

The Capital Asset Valuation for Amenity Trees[5] (CAVAT) tool was also used as a companion to the i-Tree Eco assessment. CAVAT was applied to the data from additional field visits to provide an amenity valuation for the trees.

Tree Structure and Composition	Species diversity. Dbh size classes. Leaf area. % leaf area by species.
Ecosystem Services	Air pollution removal by urban trees for CO, NO^2, SO^2, O^3 and $PM_{2\cdot5}$ % of total air pollution removed by trees. Current Carbon storage. Carbon sequestered. Stormwater Attenuation (avoided Runoff)
Structural and Functional values	Replacement cost in £. Carbon storage value in £. Carbon sequestration value in £. Pollution removal value in £. Avoided runoff in £.
Potential insect and disease impacts	Acute Oak Decline and Oak Processionary Moth Hymenoscyphus fraxineus and Massaria Beech Bark disease Asian Longhorn Beetle and Emerald Ash Borer Gypsy Moth

Table 2: Study outputs.

For a fuller description of the model calculations and field work see Appendix IV.

[4]For further details on i-Tree Eco see www.itreetools.org

[5]For further information on CAVAT see www.ltoa.org.uk/resources/cavat

Results – The Structural Resource & Tree Characteristics

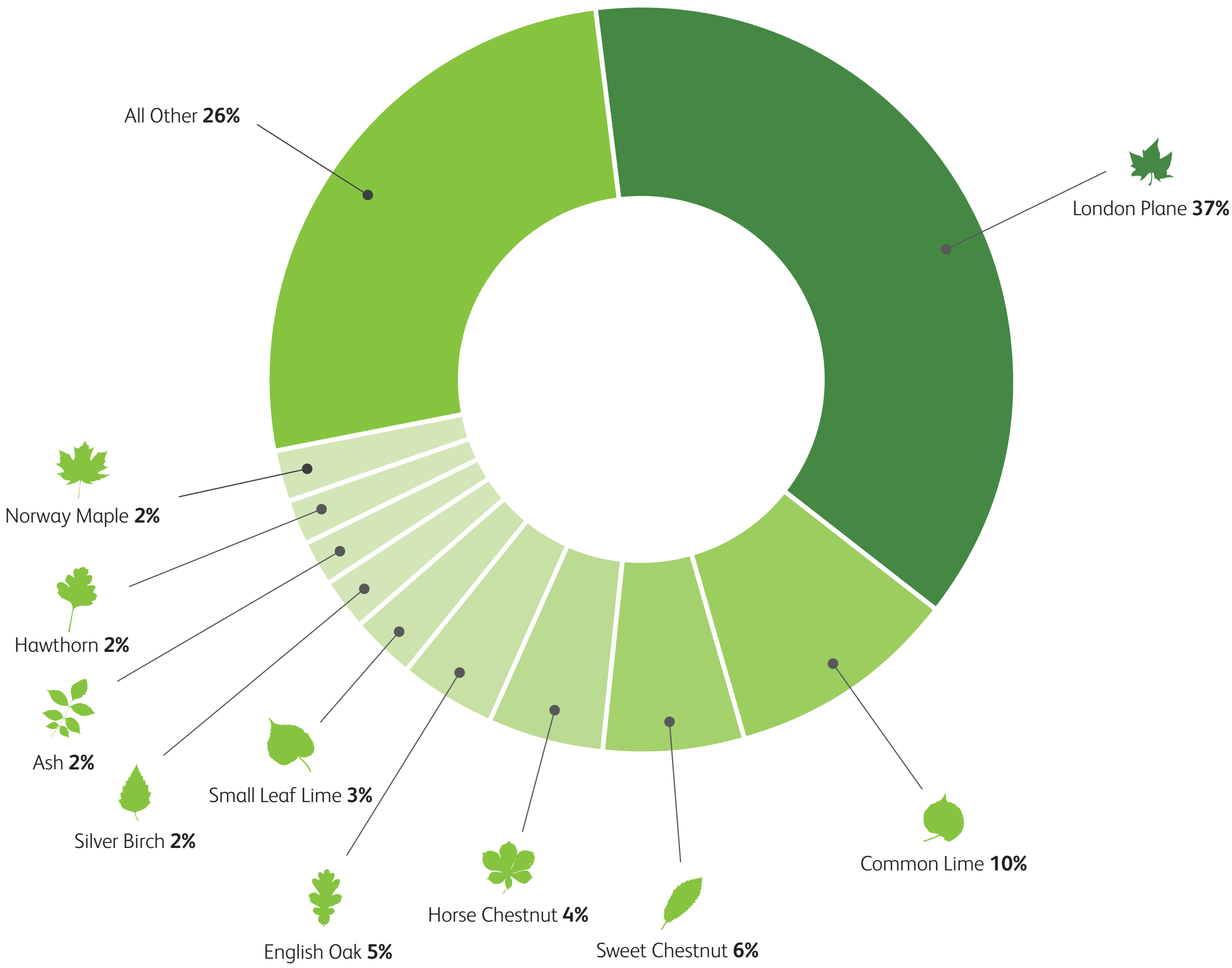
Tree species

37% of the 3,174 in Hyde Park trees are London Plane's (Platanus × acerifolia), making it the most common tree within the park. The second, third and fourth most common trees are, respectively, common lime (Tilia x europaea), sweet chestnut (Castanea sativa) and english oak (Quercus robur).

These four species account for over half of all trees in the Royal Parks. They are all large trees forming long lived elements within the landscape.

Figure 2 (below) shows the ten most common tree species as percentages of the total tree population.

Figure 2: Percentage population of tree species



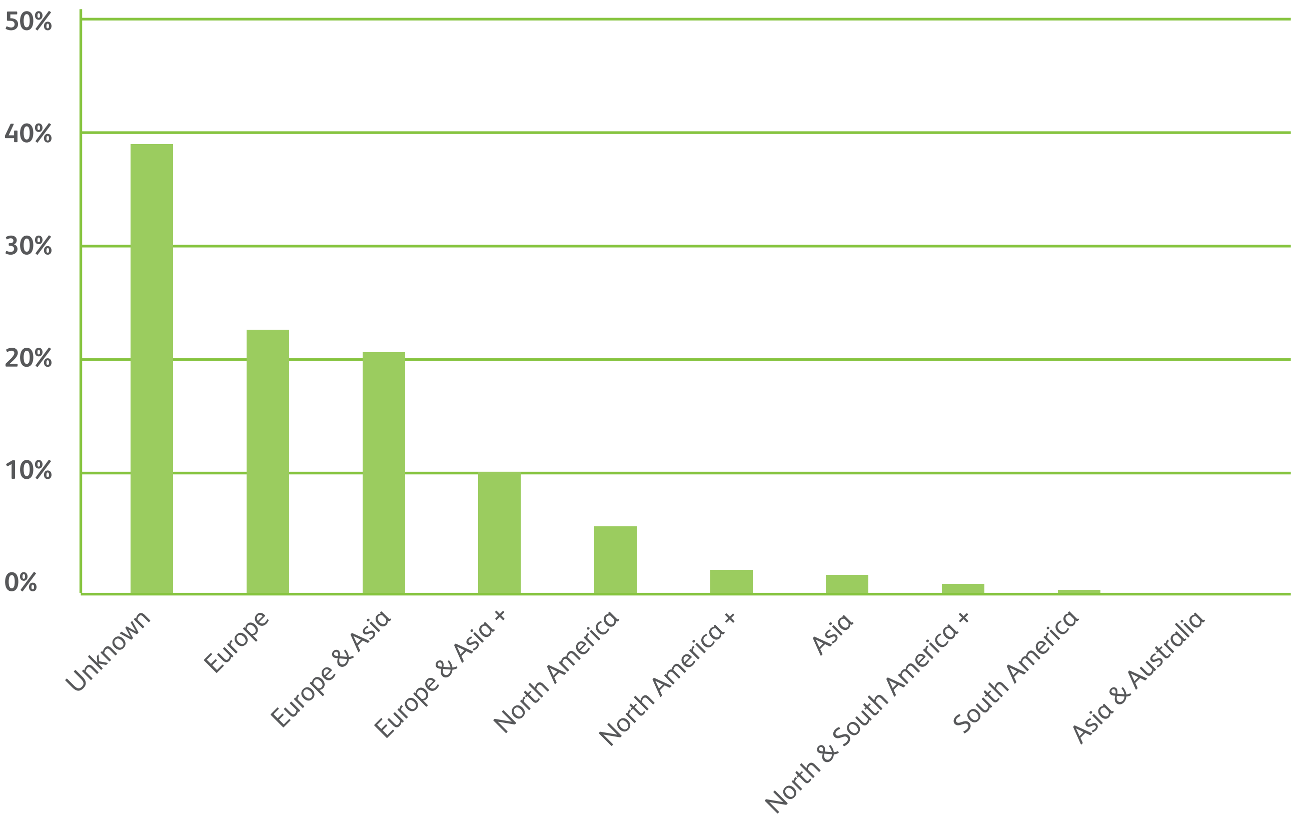
Tree diversity

Diversity is an important element of the tree population. Diversity increases overall resilience in the face of various stress inducing factors.

Diversity is important within (i.e. genetic diversity of seedlings) and between species of trees, in terms of different genera or families (i.e. Acer (maple family); Ligustrum (Olive family)). A more diverse tree-scape is better able to deal with possible changes in climate, the effects of increased pollution or the outbreak of disease.

The tree population in the Hyde Parks is considered a diverse community given its size, with 104 species of tree, from 45 genera identified.

Figure 3. Origin of tree species



Note: The + sign indicates that the species is native to another continent other than the continents listed in the grouping. For example, Europe & Asia + indicates that the species is native to Europe, Asia, and one other continent.

Size distribution

Size class distribution (or size diversity) is also important 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.

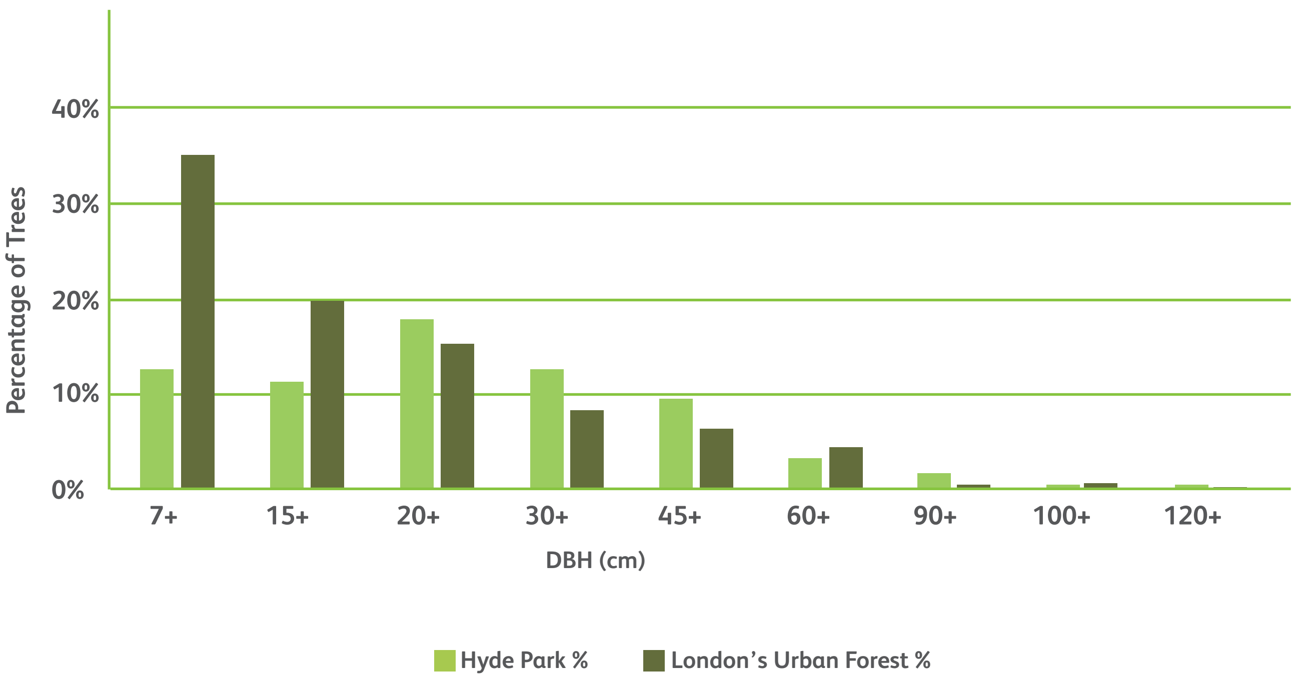
In this survey trees were sized by their stem diameter at breast height (DBH) at 1.5m. Figure 4 (below) shows the percentage of tree population by DBH class.

Those trees with smaller stem diameters (less than 15cm) constitute 12% of the total population. Trees with stems greater than 1m represent less than 1% of the population. The most common stem class for trees measured in Hyde Park is the 23-30.5cm category (18%).

Hawthorn, Ash and Birch are mostly represented in the lower DBH classes. On the other hand, 35.8% of London Planes have a stem diameter over 91.5cm. Figure5 (right) shows the number of trees within each species that falls in the different DBH classes; it therefore does not represent the predominance of the London plane, which is more apparent in the following chart.

Size distribution is compared with the overal actual picture across London's urband forest[1] in figure 4 below.

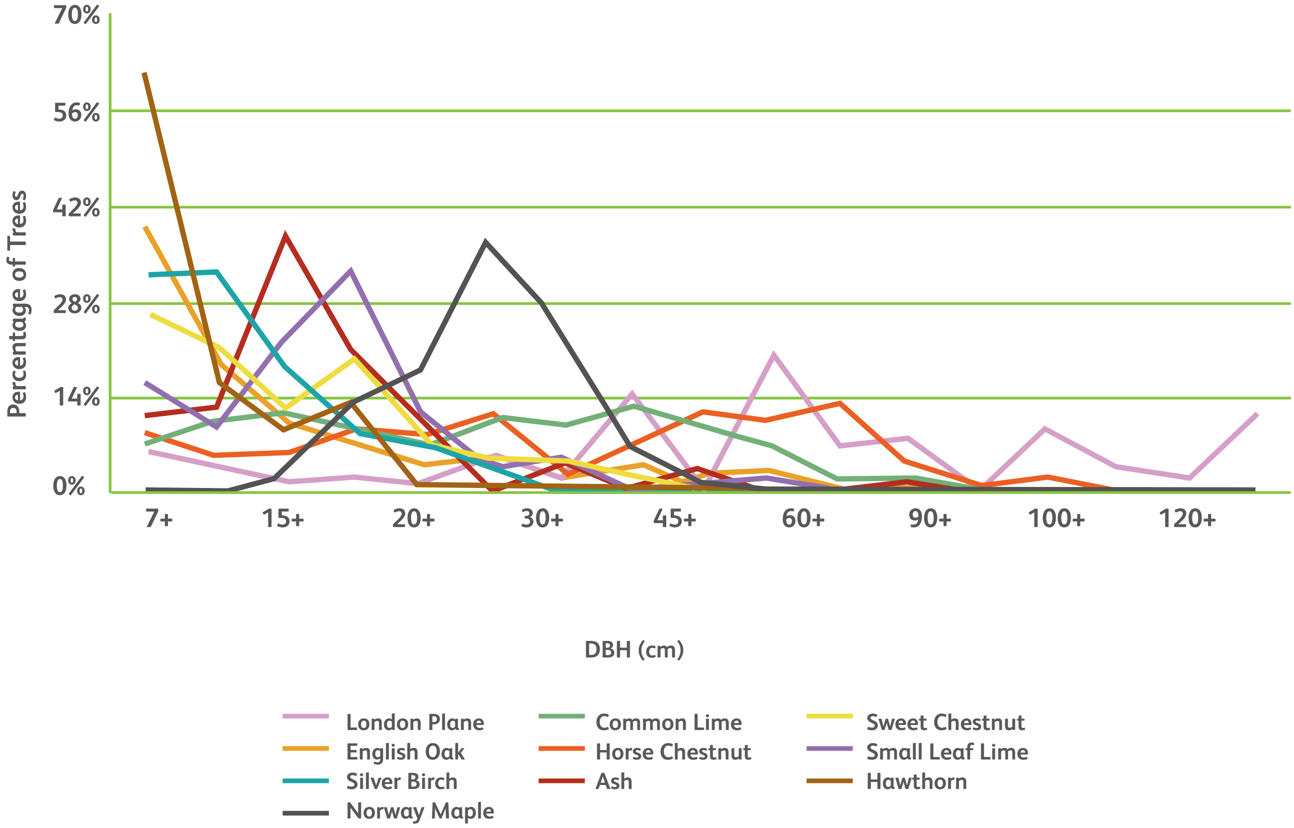
Figure 4: % DBH distribution by class



Note: Where the goal is to have a continuous cover of trees in a landscape or woodland, a guiding principle is an inverse J curve of age classes going from many young to mature trees. DBH can be considered a proxy age class, although careful consideration to the species of trees and their potential ultimate size and form must be taken to interpret this information and make informed management decisions. Different species of trees have varying optimal capacity that they can grow to. This can skew the interpretation of the field data when being analysed for interpreting size class distribution.

[1](Rogers et al 2015)

Figure 5: Percentage DBH Class by most significant species.



Tree cover and leaf area

Many of the benefits provided by trees equate directly to the amount of healthy leaf surface area. Leaf area is related to, but is not the same as, canopy cover. Canopy cover reflects the 'umbrella' or drip-line area covered by the trees, whereas leaf area includes the combined area of all leaves at different heights (layers) within the tree canopy.

Leaf area will directly affect photosynthesis and growth, and therefore carbon sequestration and storage, as well as the ability to capture airborne pollutants and intercept rainfall.

Canopy cover

Tree canopy cover, also referred to as canopy cover, can be defined as the layer of combined leaves, branches and stems of trees that cover the ground when viewed from above[6].

Tree canopy cover is a two dimensional metric, indicating the spread of canopy cover across a given area. At the most basic level, tree canopy cover can tell us how much tree cover there is in a particular area and highlight available opportunities to plant more trees[7].

Tree canopy cover for Hyde Park was calculated at 34.5%. By way of comparison, in the surrounding landscape, average canopy cover for London is estimated at 20.3 %[8].

Figure 6: Hyde Park canopy cover map

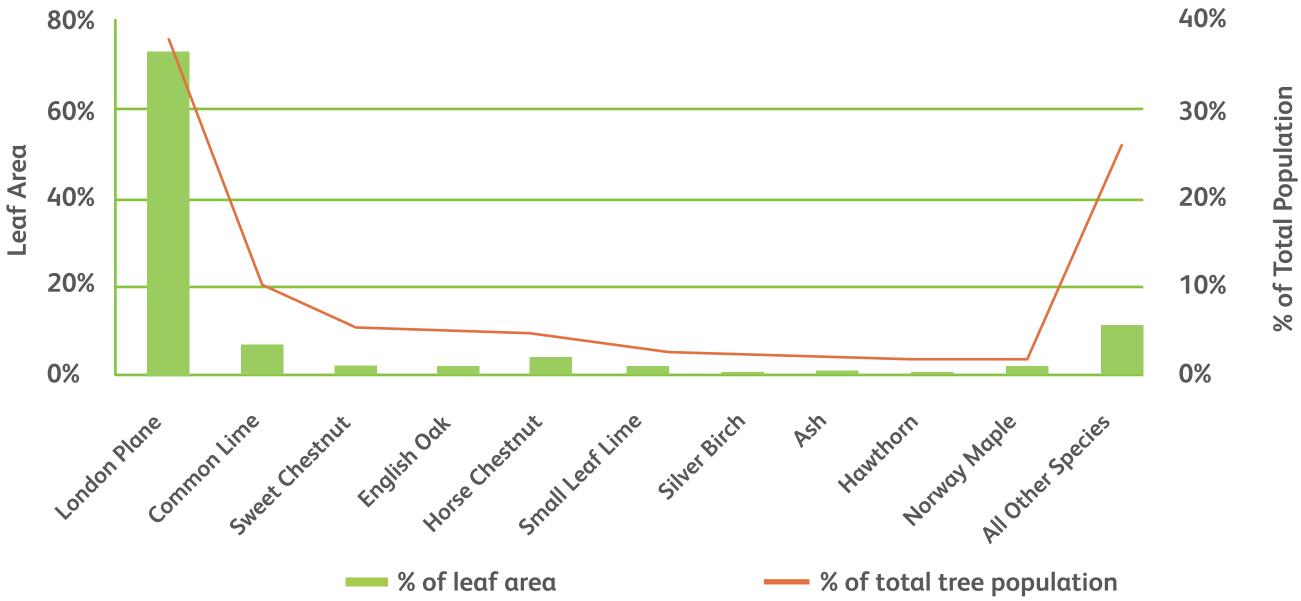
[6] (Grove et al., 2006) [7](Rodbell and Marshall, 2009)) [8] (Rogers et al 2015)

Leaf area

Within Hyde Park, the total leaf area is estimated at 2,577,100 m^2. The total study area is 1,420,000 m^2. If all the layers of leaves within the tree canopies were spread out, **they would cover more than 1.8 times the area of the Hyde Park.**

The three most dominant species in terms of leaf area are London Plane (72.1 %), Common Lime (6.4 %) and Horse chestnut (3.4 %). Figure 7 shows the most dominant trees' contributions to total leaf area. In total these 10 species (representing 75 % of the trees by population) contribute 89 % of the total leaf area. The remaining 25 % of trees provide the other 11 % of leaf area.

Figure 7: Percentage leaf areas of the ten most dominant trees



The London Plane provides more than twice the leaf area of all other tree species combined, making them particularly important for providing benefits to the Hyde Park.

Larger trees have a greater functional value and provide increased benefits (details of functional value and the resulting benefits are discussed later).

It has been estimated[9] that a 75 cm diameter tree can intercept 10 times more air pollution, can store up to 90 times more carbon and contributes up to 100 times more leaf area to the tree canopy than a 15 cm tree.

Generally it is the larger trees, which in this case are also the most common species, that contribute more leaf area.

[9]Every Tree Counts – A portrait of Toronto's Urban Forest

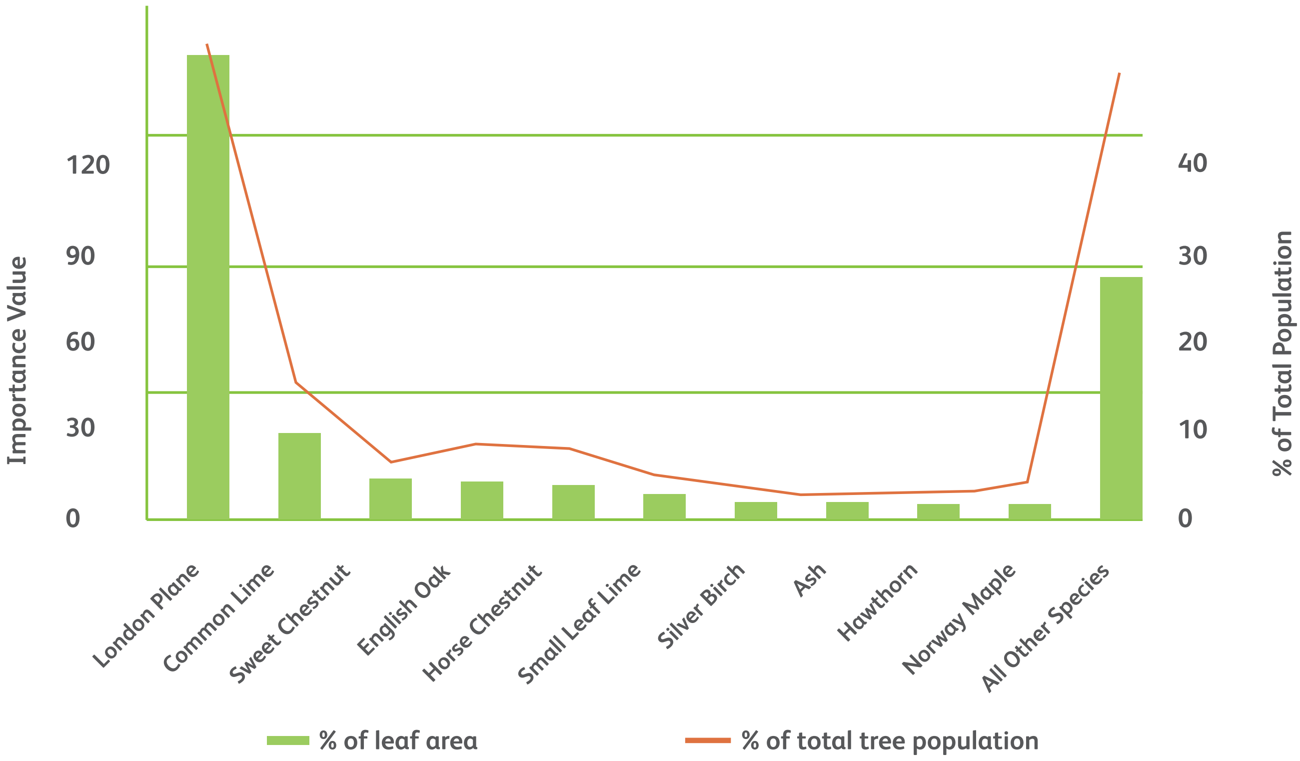
Importance value – dominance

Within the i-Tree Eco model, leaf area metrics are combined with species population data to provide an 'importance value' for each tree species. However, a high importance value does not necessarily mean that these trees should be used in the future. Rather, it shows which species are currently delivering the most benefits based on their population and leaf area. For this reason it is also referred to as Species Dominance.

These species currently dominate the treescape within the park and are therefore the most important in delivering environmental benefits. The 10 most dominant tree species are shown in figure 8. A full list of importance values is given in Appendix II.

The London Plane is by far the most dominant tree in the Hyde Park, with an importance value of 109.6 , over six times the value of the Common Lime, the second most dominant tree in the Park.

Figure 8: Dominance of the ten most common tree species



Results – Ecosystem Services Resource

Air Pollution Removal

Poor air quality is a common problem in many urban areas and along road networks. Air pollution caused by human activity has become an increasing problem since the beginning of the industrial revolution.

With the increase in population and industrialisation, and the use of transport based on fossil fuels, large quantities of pollutants have been produced and released into the urban environment. The problems caused by poor air quality are well known, ranging from human health impacts to damage to buildings.

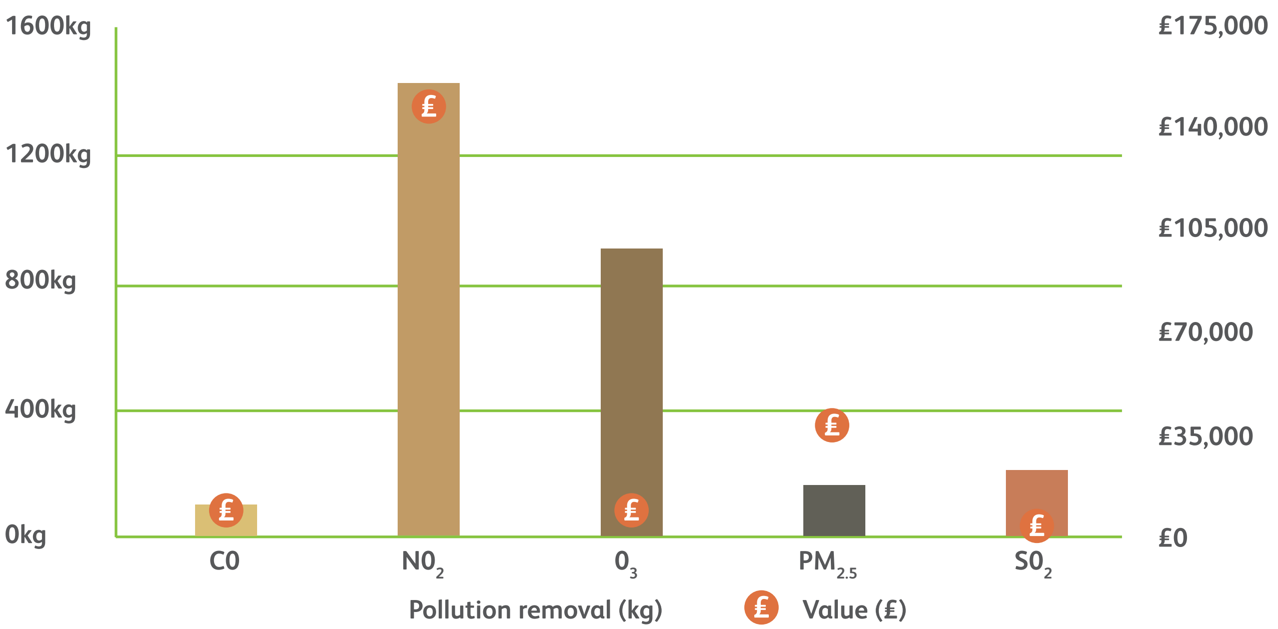
Urban trees can help to improve air quality by reducing air temperature and by directly removing pollutants from the air[10] and intercepting and absorbing airborne pollutants through leaf surfaces[11]. By removing pollution from the atmosphere, trees reduce the risks of respiratory disease and asthma, thereby contributing to reduced health care costs[12].

London has particularly high levels of air pollution, so the trees within Hyde Park provide a valuable service.

The situation is complicated by the fact that trees also emit volatile organic compounds (VOCs) that can contribute to low-level ozone formation. However, integrated studies have revealed that an increase in tree cover leads to a general reduction in ozone through a reduction in the urban heat island effect[13].

The i-Tree software accounts for both reduction and production of VOCs within its algorithms, and the overall effect of Hyde Park's trees is to reduce ozone through evaporative cooling.[14]

Table 9: Value of the pollutants removed and quantity per-annum within Hyde Park.



Since different tree types may emit VOCs at different levels, species choice is also an important consideration. Donovan[15] has developed an Urban Air Tree Quality Score which can be used as a decision support tool for this purpose.

Greater tree cover, pollution concentrations and leaf area are the main factors influencing pollution filtration and therefore increasing areas of tree planting have been shown to make further improvements to air quality[16]. Furthermore, because filtering capacity is closely linked to leaf area it is generally the trees with larger canopy potential that provide the most benefits.

[10] Tiwary et al., 2009 [11] Nowak et al, 2000 [12] Peachey et al., 2009, Lovasi et al., 2008 [13] Escobedo and Nowak (2009) [14] Nowak et al, 2006
[15] Quoted in McDonald et al., 2007 [16] Escobedo and Nowak (2009)

Fig: 10 Monthly pollution removal.

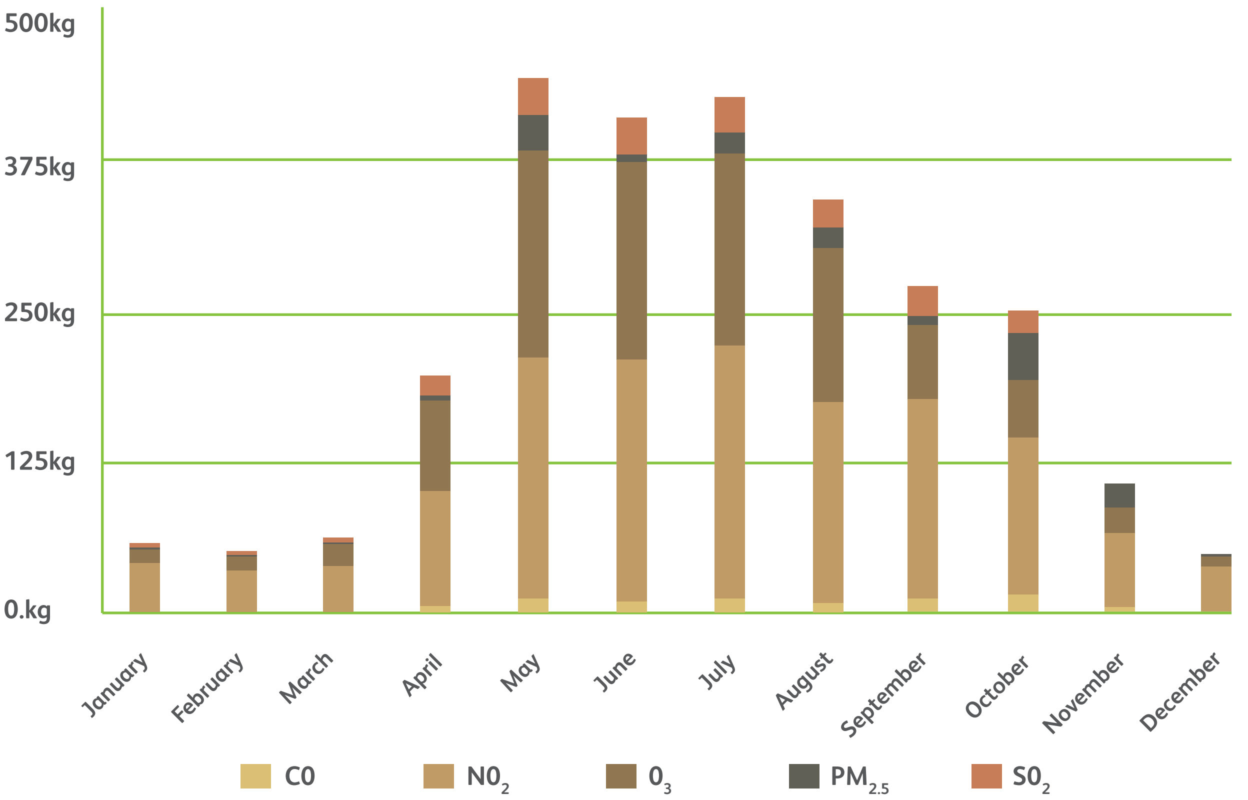
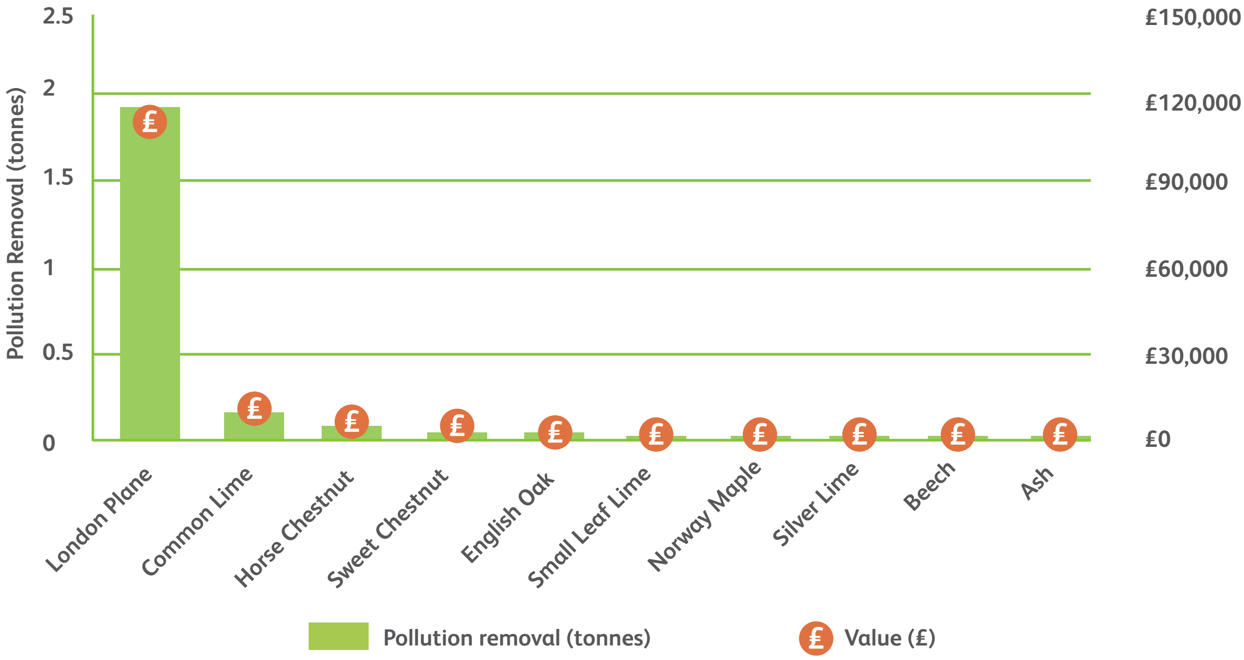


Fig 11. Pollution removal for top 10 pollutant removing species.



In total the trees in Hyde park remove 2.7 tonnes of pollution from the air every year. This is a service worth £183,454.

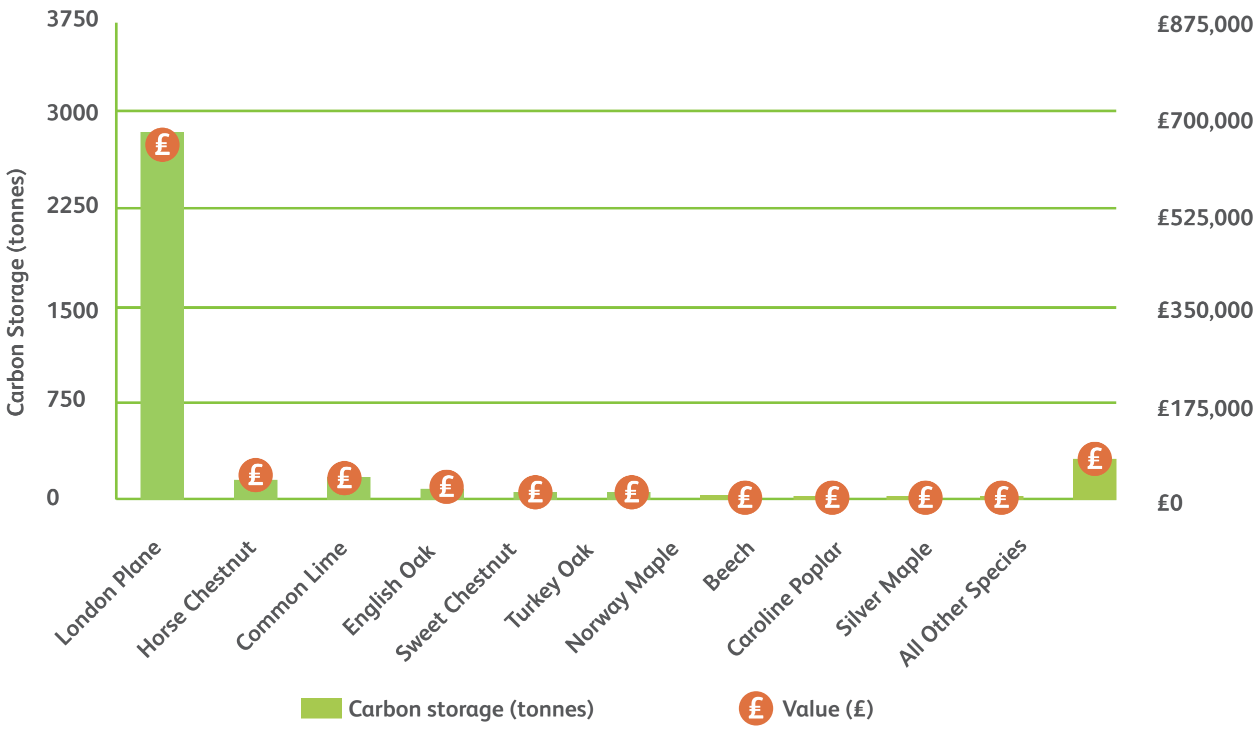
Carbon Storage and Sequestration

The main driving forces behind climate change is the concentration of carbon dioxide (CO_2) in the atmosphere. Trees can help mitigate climate change by storing and 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 up carbon for decades or even centuries[17].

Over the lifetime of a tree, several tons of atmospheric carbon dioxide can be absorbed[18].

Figure 11 illustrates the carbon storage of the top ten trees along with the value of the carbon they contain.

Figure 11: Mass and value of top ten trees by Carbon Storage



Overall the trees in Hyde Park store 3,872 tonnes of carbon with a value of £880,123.

As trees grow they store more carbon by holding it in their tissue. As trees die and decompose they release this carbon back into the atmosphere. Therefore the carbon storage of trees and woodland is an indication of the amount of carbon that could be released if all the trees died.

Maintaining a healthy tree population will ensure that more carbon is stored than released. Utilising the timber in long term wood products or to help heat buildings or produce energy will also help to reduce carbon emissions from other sources, such as power plants.

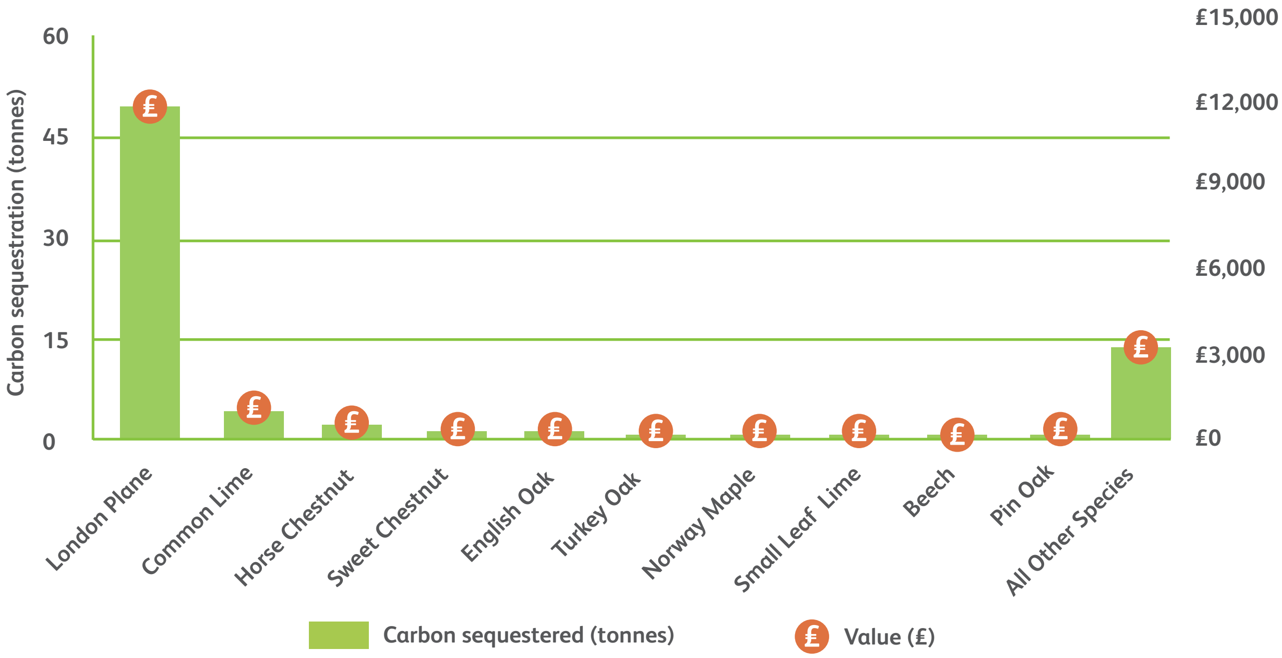
[17] Kuhns, 2008
[18] McPherson, 2007

Carbon sequestration

Carbon sequestration is calculated from the predicted growth of the trees based on field measurements and climate data. This provides a volume of tree growth. This volume is then converted into tonnes of carbon based on species specific conversion factors and then multiplied by the unit cost for carbon.

Hyde Park's trees annually sequester 66 tonnes of carbon per year, with a value of £20,028. Figure 12 shows the ten trees that sequester the most carbon per year and the value of the benefit derived from the sequestration of this atmospheric carbon.

Figure 12: Mass and value of carbon sequestered by the top ten trees



Of all the tree species inventoried, the London Plane stores and sequesters the most carbon, adding 51 tonnes every year to the current London Planes carbon storage of 2,938 tonnes. This represents 76 % of the total carbon stored by the entire tree stock and is a reflection of the size and population of the plane trees.

Stormwater Run-Off

Surface run-off can be a cause for concern in many areas as it can contribute to flooding and a source of pollution in streams, wetlands, rivers, lakes, and oceans.

During precipitation events, a portion of the precipitation is intercepted by vegetation (trees and shrubs) while a further portion reaches the ground. Precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff[19].

In urban areas, the large extent of impervious surfaces increases the amount of runoff[20]. However, trees are very effective at reducing surface runoff. Trees intercept precipitation, while their root systems promote infiltration and storage in the soil.

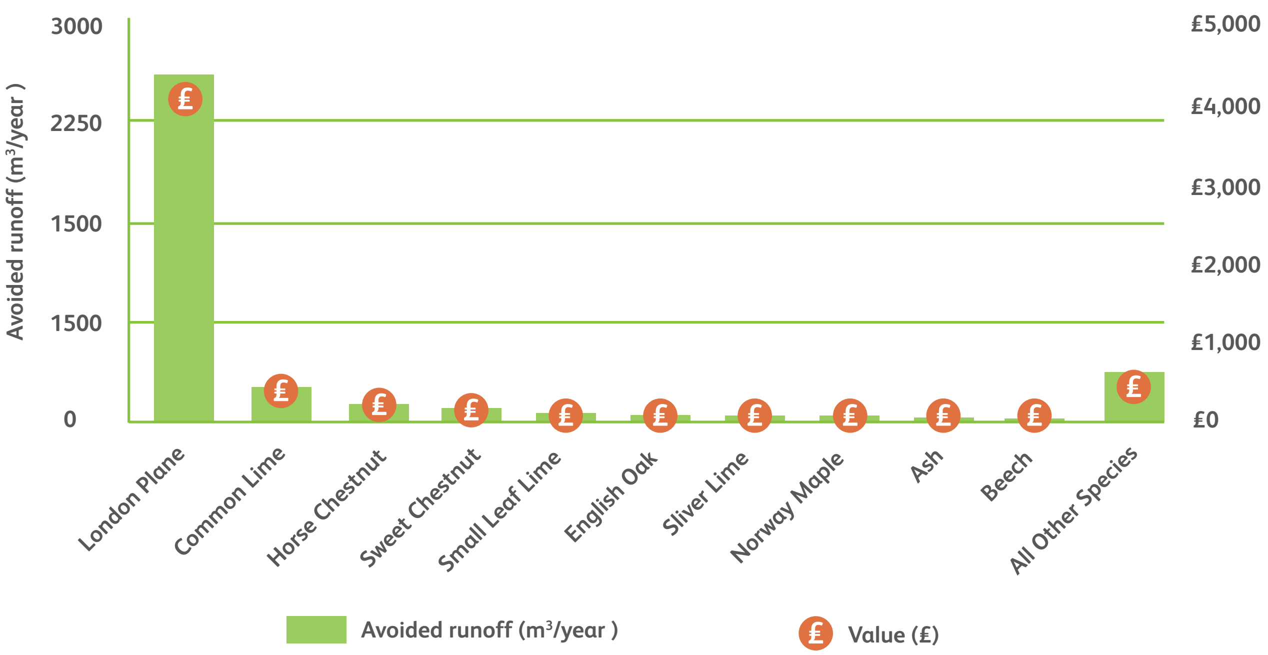
Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation.

The trees of the Hyde Park help to reduce runoff by an estimated 3,584m^3 a year with an associated value of £5,434.

3,584m^3 is equivalent to 1.4 olympic swimming pools of stormwater averted every single year.

Figure 13 shows the volumes and values for the ten most important species for reducing runoff.

Figure 13: Avoided runoff by species



It is clear that the London plane has an important role in reducing runoff in Hyde Park: the planes intercept more than half of the precipitation, reducing runoff by more than all the other trees put together.

[19]Hirabayashi (2012).
[20]Trees and Design Action Group (2014)

Replacement Cost

In addition to estimating the environmental benefits provided by trees, the i-Tree Eco model also provides a structural valuation which in the UK 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 (Hollis, 2007).

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 figure 14 below.

The total value of all trees in the study area currently stands at £12,246 million.

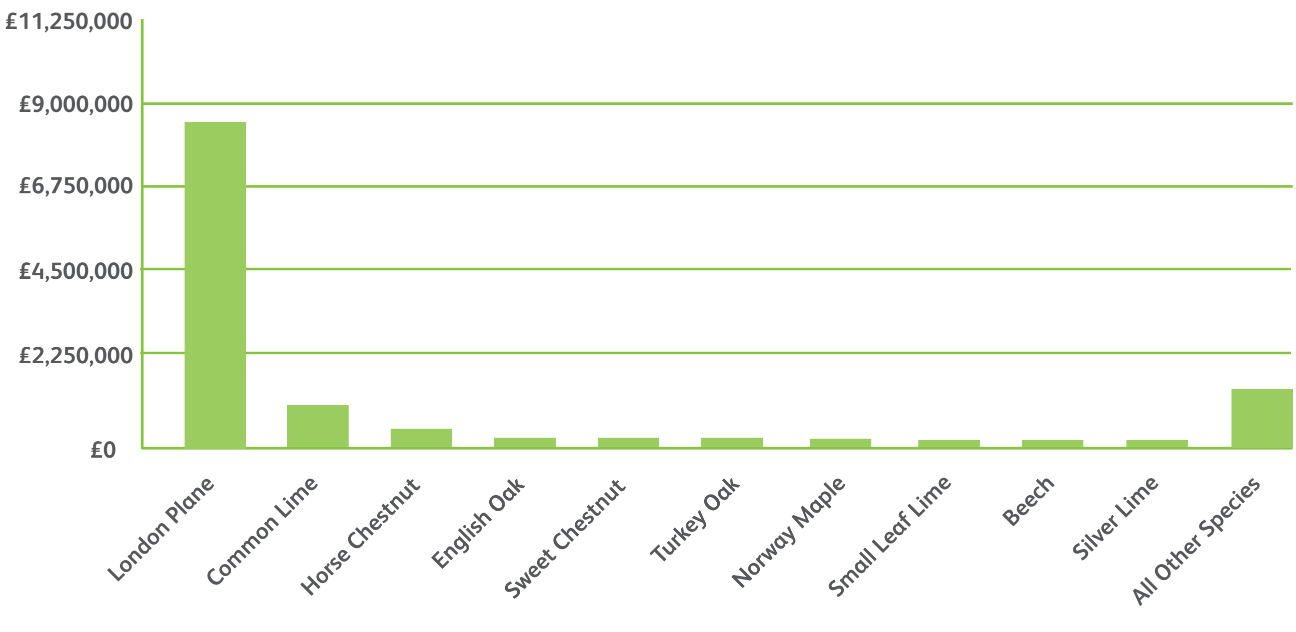
London Plane is the most valuable species of tree in Hyde park, on account of both its size and population, followed by Common Lime and Horse Chestnut. These three species of tree account for £ 9,944 million (81 %) of the total replacement cost of the trees in Hyde Park.

A full list of trees with the associated replacement cost is given in Appendix III.

Trees and woodlands have a structural value which is based on the depreciated replacement cost of the actual tree.

Large, healthy long lived trees provide the greatest structural and functional value.

Fig 14: Replacement Cost of the ten most valuable tree species



CAVAT – The amenity value

Capital Asset Valuation for Amenity Trees (CAVAT) is a method developed in the UK to provide a value for the public amenity that trees provide, rather than the property approach taken in the CTLA method. The two methods are often confused but are in fact addressing two different aspects of Hyde Parks trees.

Whilst CTLA provides a replacement cost for management purposes, CAVAT includes the addition of the Community Tree Index (CTI) factor, which adjusts the CAVAT value to take account of the greater amenity benefits of trees in areas of higher population density, using official population figures. This adds a further social dimension, placing a value on the trees visual accessibility and prominence in the landscape.

The relative importance of the mature component of the tree population is clear. Their high CAVAT scores reflect their importance as major elements of the treescape of central London. It also highlights the priority that needs to be placed in securing their continued health and in planting a wide variety of large growing successor species for the future.

The total amenity value for all the trees in Hyde park is £172,843,688.

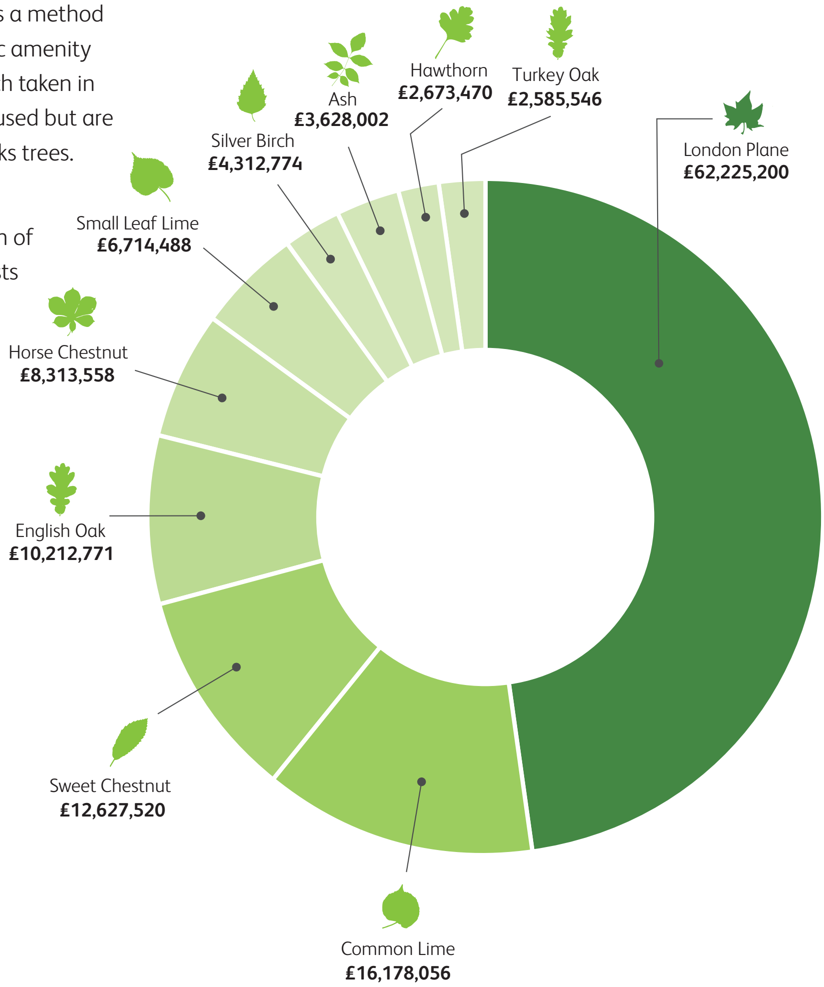
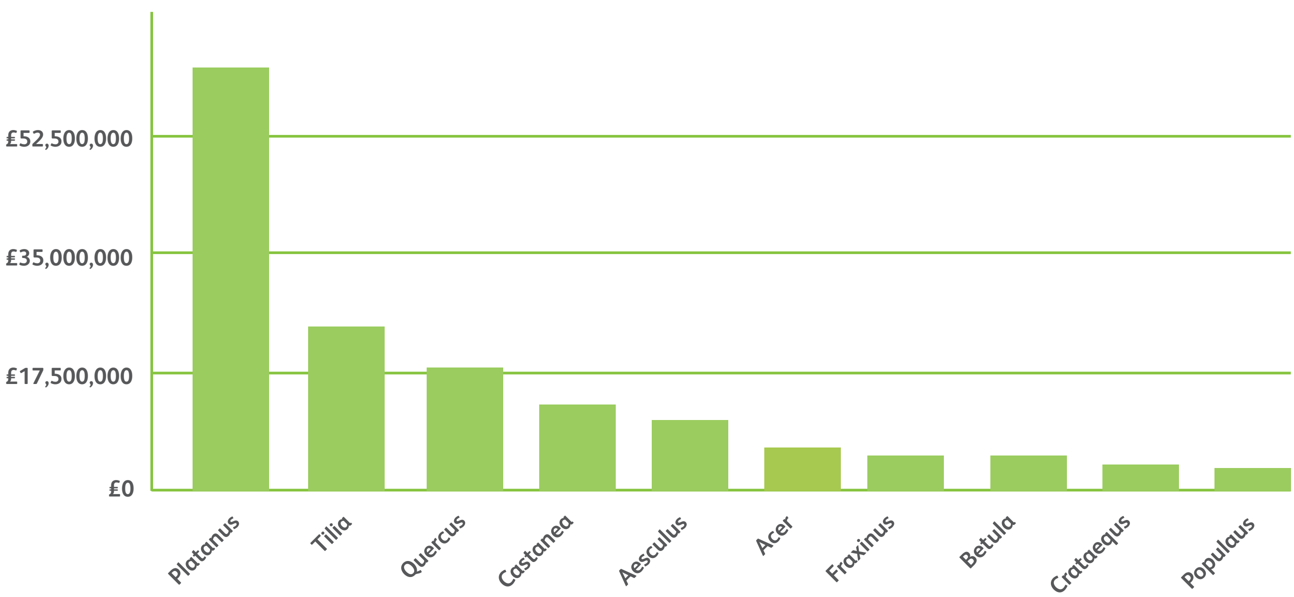


Fig 15: Value of CAVAT value by species

Fig 16: Percentage of CAVAT value by genus



Potential Pest and Disease Impacts

Various insects and diseases can potentially kill trees, consequently reducing the value and sustainability of our urban forests. As most pests generally tend to have specific tree hosts, the potential damage that can be caused by each pest will differ.

In this chapter, 7 pests and diseases have been selected to illustrate how the results from this survey can be used to estimate and tackle the potential pathogen impacts on the trees of Hyde Park.

These pathogens have the potential to reduce the health and even kill a number of trees that are present in the Park. This would also reduce the value of ecosystem services provided by the trees.

Figure17 shows the pathogens, the potential percentage of population that could become infected and those that are immune.

In an analysis of 18 years data, researchers found that Americans living in areas infested by Emerald Ash Borer beetle suffered an additional 15,000 deaths from cardiovascular disease and 6,000 more deaths from lower respiratory disease when compared to uninfected areas.

Figure 17: Potential pest and disease susceptibility

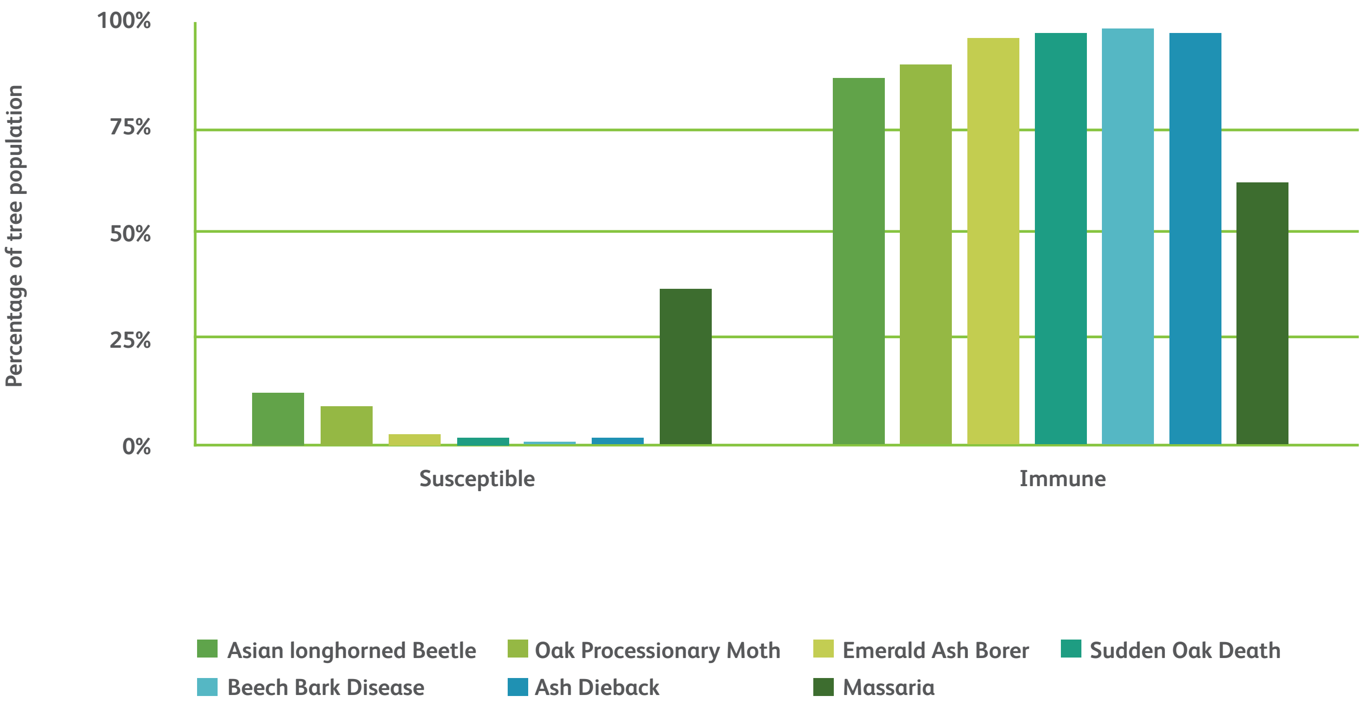
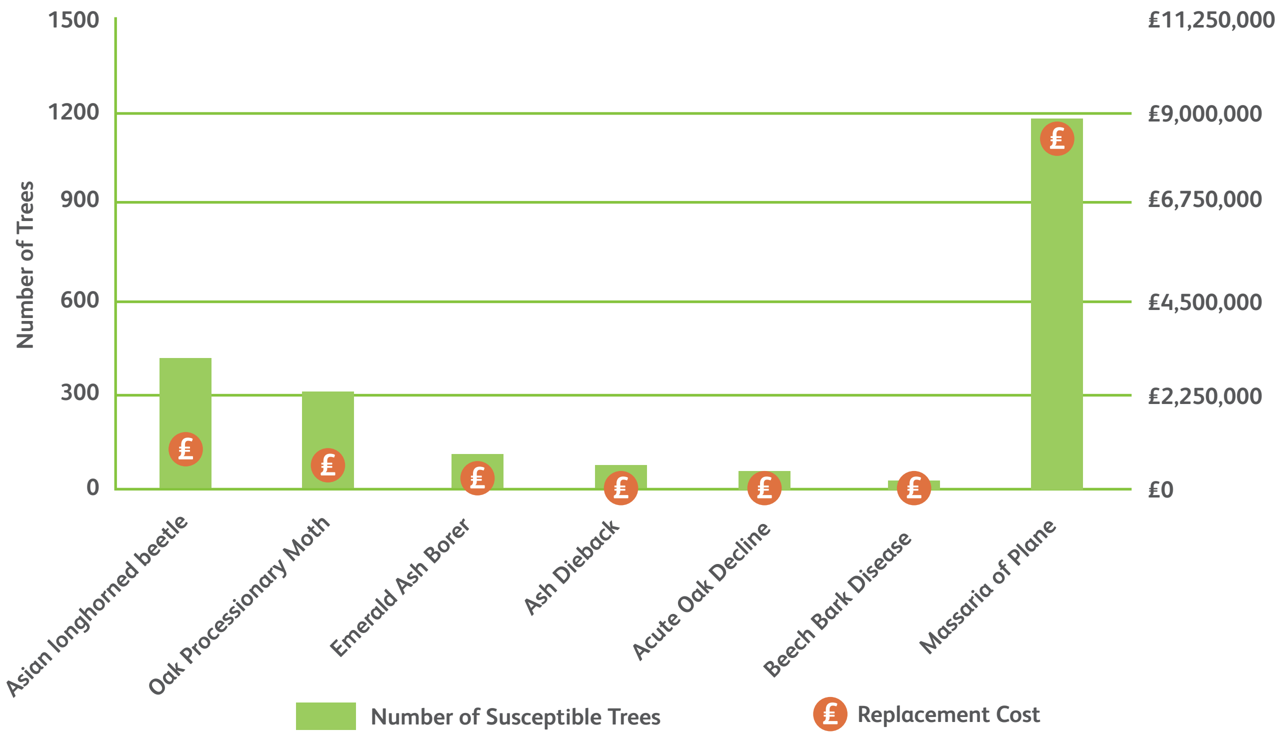
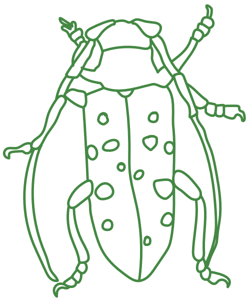


Fig 18 (below) illustrates the potential cost of replacing trees following an outbreak by the pathogens investigated.

Figure18: Potential pest and disease impacts – number of trees susceptible and their replacement costs.



Potential Pest and Disease Impacts



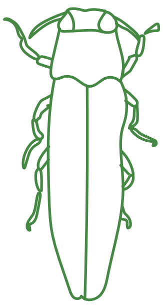
Asian Longhorn Beetle (ALB)

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 Hyde Park.

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 removed by the Forestry Commission and the Food and Environment Research Agency(FERA)).

It is estimated by the United States Department of Agriculture Forest Service[21] that unless the spread of the beetle is contained, the beetle could result in up to 30 % tree mortality across the United States.

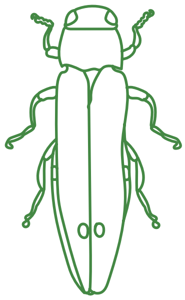
As the more common families of trees contained within Hyde Park are preferential for the beetle it is possible that an outbreak could affect 13 % of the tree population. It would potentially cost £1,000,000 to replace the effected trees.



Emerald Ash Borer (EAB)

A native of Asia, the beetle has caused the deaths of millions of ash trees in the United States, and once established containment 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 kills 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. It has the potential to affect 3.2 % percent of the tree population of Hyde park (£130k in replacement cost).



Acute Oak Decline (AOD)

There have been episodes of 'oak decline' documented for almost 100 years, and it is regarded as a complex disorder whereby typically several damaging agents interact. The outcome often results in high levels of mortality, but trees can sometimes also recover. Two key types of decline have been identified: Chronic Oak Decline (COD) – decline tends to be slow (10 – 50 years) and the focus is often on roots, and Acute Oak Decline (AOD) where decline tends to be fast (2 – 5 years) and the focus is on above ground parts.

The distinction between the two is often based on the rate of decline and both can occur together or one lead to the other. Conditions that make oak trees susceptible to AOD maybe 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).

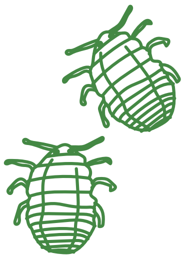
The most recent episode of AOD has to date occurred predominantly in the SE and Midlands. Its distribution in the UK over recent years has however slowly intensified and spread to include Wales, East Anglia, with occasional occurrences in the South West.

Once the disease has occurred, generally the infected trees are retained unless there is an imminent concern regarding safety. Due to the close proximity of a high value target i.e. the carriageways within Hyde Park, removals may therefore be necessary. Alternatively, if limited numbers of trees appear infected then 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 2 % percent.

(£116,000 in replacement cost).

[21] www.na.fs.fed.us/pubs/palerts/alb/alb_pa.pdf



Beech Bark Disease

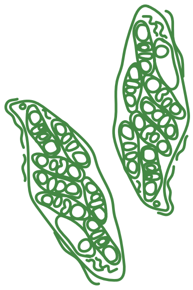
Beech bark disease (Houston and O'Brien, 1983) is an insect-disease complex that, as the name suggests, impacts beech trees. This disease threatens 0.8% percent of the population. It would potentially cost £102,000 to replace the effected trees.

Ash Dieback (Hymenoscyphus fraxineus)

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

It has had a major impact upon the ash population in several countries e.g. Denmark, and 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. Whilst initially occurring predominantly in ash populations that had been recently planted, 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 2.2% of the population, It would potentially cost £71,000 to replace the effected trees.



Massaria

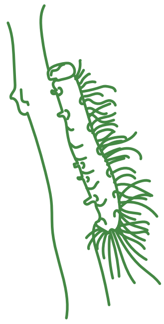
Massaria disease (Splanchnonema platini) is a fungal disease which affects London Plane trees (Platanus x acerifolia). Massaria causes large legions on the upper surfaces of major branches which can cause branch drop.

It is a fast acting disease which means regular inspections are required to identify the infection as early as possible. On smaller limbs the infection can be identified clearly by a sudden decline in vigour with dieback and premature defoliation apparent plus rapid flaking bark exposing the sapwood.

On larger limbs the signs are less obvious although there may be secondary fruiting bodies along the upper side of the branch or dead twigs arising from the upper side of the dead branch.

Given the number and stature of the plane trees within Hyde Park this particular pathogen is a very significant threat to the tree population and delivery of benefits.

Massaria poses a significant threat to 37.4% of the population, It would potentially cost £8,636 million to replace the effected trees.



Oak Processionary Moth (OPM)

Oak Processionary Moth (Thaumetopoea procession) was introduced into the UK in 2005. The caterpillars can affect the earth 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 skin irritations and breathing problems due to the tiny hairs located on their bodies.

OPM was first identified in Richmond Park but is now present in all the Royal Parks. It is a real threat to both the oak trees and members of the public in Hyde park, potentially affecting 2% of the tree population.

Tree Condition

By far the most important factor when dealing with any potential pest or disease impact is to consider the health of the tree. Tree condition was measured as part of the survey and fig 19 below shows the overall health of the trees in Hyde Park.

Tree condition also directly affects the ecosystem services each tree provides. The majority of the trees within Hyde park are in excellent condition.

Fig19: Overall tree condition.

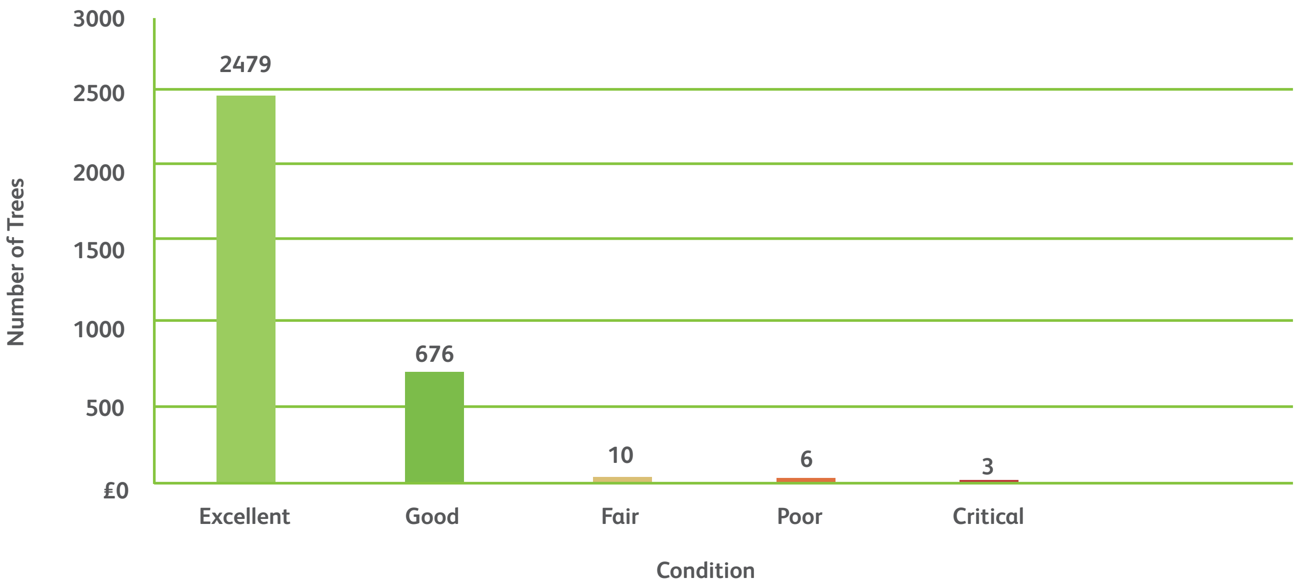
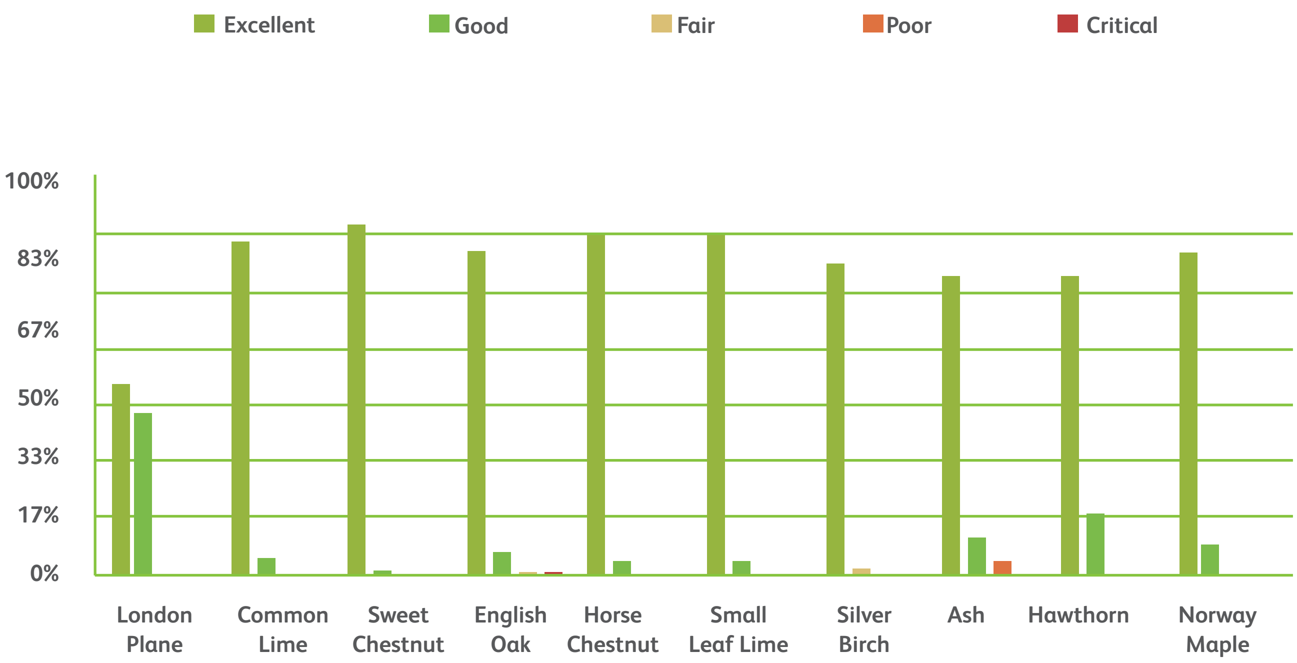


Fig20: Condition of the 10 most common trees.

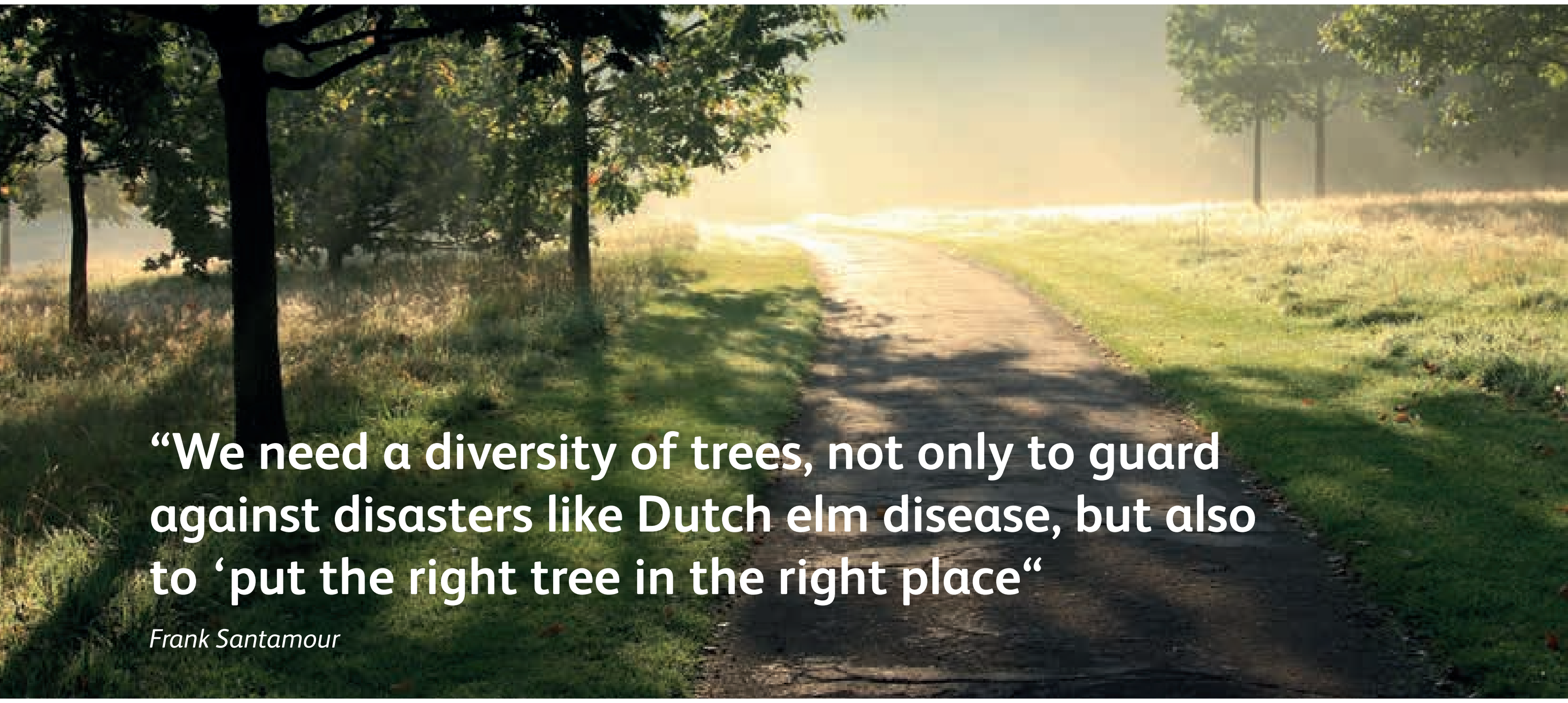


Recommendations for using this study

The results and data from previous i-Tree studies have been used in a variety of ways to better manage trees and inform decision making. With better information we can make better decisions and this is one of the biggest benefits from undertaking a project such as this.

- Data can be used to inform species selection for increased tree diversity thereby lessening the impacts from potential threats like massaria.
- Use the report and data to produce educational and public information about Hyde Park's trees.
- Use the data for cost benefit analysis to inform decision making.
- Undertake a gap analysis to help inform where to plant trees to optimise ecosystem services and maximise the benefits, to align to the objectives and priorities of the Royal Park and the Hyde Park management plan.
- Size does matter! Identify trees that can grow on to full maturity and become the optimal canopy size and contribute the most benefits to the surrounding urban communities. Review together with an ancient tree management plan that included non natives and heritage trees to broaden the potential for the parks trees to build resilience to future change.
- Use the approach and findings presented in this report to inform the development of Royal Parks other strategies.
- Use the findings from this report to put together a business case for research into tree diversity with RBG Kew and Treeconomics.

Conclusions



The tree population of Hyde Park is generally healthy and has a good structural, species and age diversity. This will provide some resilience from possible future influences such as climate change and pest and disease outbreaks.

However, the large proportion of plane trees (37.4%) is a future risk to the delivery of benefits (for example if Plane wilt (*Ceratocystis fimbriata f. platani*) becomes prevalent in the UK).

The concept of trees as part of our public health infrastructure is a reality. Hyde Parks trees provide a valuable public benefit - at least £209,000 in environmental services each year.

Furthermore, the values presented in this study represent only a portion of the total value of the trees in Hyde Park.

Trees confer many other benefits, such as contributions to our health and well being that cannot yet be quantified and valued. Therefore, the values presented in this report should be seen as conservative estimates.

The extent of these benefit needs to be recognised, and strategies and policies that will serve to conserve this important resource (through stakeholder education for example) would be one way to address this.

As the amount of healthy leaf area equates directly to the provision of benefits, future management of the tree stock is important to ensure canopy cover levels continue to be maintained or increased.

This may be achieved via new planting, but the most effective strategy for increasing average tree size and the extent of tree canopy is to preserve and adopt a management approach that enables the existing trees to develop a stable, healthy, age and species diverse, multi-layered population.

Climate change could affect the tree stock in all the Royal Parks in a variety of ways and there are great uncertainties about how this may manifest. Further research into this area would be useful in informing any long term tree and parkland strategies such as species choice for example.

The challenge now is to ensure that policy makers and practitioners take full account of parkland trees in decision making. Not only are trees a valuable functional component of our landscape they also make a significant contribution to peoples quality of life.

Appendix I. Relative Tree Effects

The trees in Hyde Park provides 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 only as they are largely based on US values (see footnotes).

Carbon storage is equivalent to:

- Annual carbon emissions from 3,020 family cars
- Annual carbon emissions from 1,240 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 222 family cars
- Annual nitrogen dioxide emissions from 100 single-family houses

Sulphur dioxide removal is equivalent to:

- Annual Sulphur dioxide emissions from 2,240 family cars
- Annual Sulphur dioxide emissions from 6 single-family houses

Annual carbon sequestration is equivalent to:

- Annual carbon emissions from 100 family cars

Average passenger automobile emissions per mile were based on dividing total 2002 pollutant emissions from light-duty gas vehicles[1] divided by total miles driven in 2002 by passenger cars[22].

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[23].

Carbon dioxide emissions from automobile assumed six pounds of carbon per gallon of gasoline if energy costs of refinement and transportation are included[24].

[22] National Emission Trends http://www.epa.gov/ttn/chief/trends/index.html)

[23] National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/.

[24] 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).

Appendix II. Species Importance Ranking List

Rank	Scientific Name	Common Name	%Population	% Leaf Area	IV [a]
1	Platanus x acerifolia	London plane	37.40	72.10	109.60
2	Tilia x europaea	Common lime	10.20	6.40	16.60
3	Aesculus hippocastanum	Horse chestnut	4.40	3.40	7.80
4	Castanea sativa	Sweet chestnut	5.60	1.80	7.40
5	Quercus robur	English oak	5.30	1.30	6.70
6	Tilia cordata	Small leaf lime	3.20	1.40	4.60
7	Fraxinus excelsior	Ash	2.20	0.90	3.10
8	Acer platanoides	Norway maple	1.80	1.30	3.00
9	Tilia tomentosa	Silver lime	1.70	1.20	2.90
10	Betula pendula	Silver birch	2.40	0.40	2.80
11	Crataegus monogyna	Hawthorn	2.10	0.20	2.30
12	Quercus cerris	Turkey oak	1.30	0.70	2.00
13	Quercus palustris	Pin oak	1.40	0.40	1.80
14	Juglans regia	Walnut	1.10	0.50	1.60
15	Fagus sylvatica	Beech	0.90	0.70	1.60
16	Tilia euchlora	Crimean linden	0.80	0.40	1.20
17	Carpinus betulus	Hornbeam	0.90	0.30	1.20
18	Prunus avium	Sweet cherry	0.80	0.40	1.20
19	Prunus	Plum spp	0.90	0.20	1.20
20	Aesculus x carnea	Red horsechestnut	0.80	0.40	1.10
21	Quercus rubra	Red oak	0.70	0.40	1.00
22	Alnus glutinosa	Alder	0.80	0.20	1.00
23	Acer saccharinum	Silver maple	0.50	0.40	1.00
24	Acer pseudoplatanus	Sycamore	0.60	0.40	0.90
25	Malus	Apple spp	0.80	0.10	0.90
26	Alnus cordata	Italian alder	0.50	0.20	0.70
27	Acer campestre	Field maple	0.50	0.20	0.70
28	Populus	Poplar	0.40	0.20	0.70
29	Populus nigra	Black poplar	0.30	0.40	0.60
30	Acer cappadocicum	Cappadocicum maple	0.40	0.20	0.60
31	Quercus Quercus/live ilex	Holm oak	0.40	0.20	0.60
32	Fraxinus ornus	Flowering ash	0.40	0.10	0.50
33	Fraxinus americana	White ash	0.40	0.10	0.50

Rank	Scientific Name	Common Name	%Population	% Leaf Area	IV [a]
34	Salix alba	White willow	0.30	0.20	0.50
35	Populus nigra 'italica'	Black poplar	0.30	0.10	0.40
36	Populus x canadensis	Hybrid black poplar	0.30	0.10	0.40
37	Alnus incana	Grey alder	0.30	<0.10	0.40
38	Ailanthus altissima	Tree of heaven	0.30	0.10	0.40
39	Crataegus	Hawthorn spp	0.30	<0.10	0.40
40	Aesculus flava	Yellow buckeye	0.20	0.10	0.30
41	Robinia pseudoacacia	Black locust	0.20	0.10	0.30
42	Ilex aquifolium	English holly	0.30	<0.10	0.30
43	Sorbus aria	Whitebeam	0.20	0.10	0.30
44	Populus alba	White poplar	0.20	0.10	0.30
45	Ulmus x hollandica	Siberian elm	0.10	0.10	0.20
46	Betula utilis	Indian paper birch	0.20	<0.10	0.20
47	Fraxinus oxycarpa	Caucasian ash	0.20	<0.10	0.20
48	Salix x chrysocoma	Weeping Willow	0.20	0.10	0.20
49	Liquidambar styraciflua	Sweetgum	0.20	<0.10	0.20
50	Ginkgo biloba	Ginkgo	0.20	<0.10	0.20
51	Cladrastis kentukea	Yellowwood	0.20	<0.10	0.20
52	Quercus phellos	Willow oak	0.20	<0.10	0.20
53	Sorbus	mountain ash spp	0.10	0.10	0.20
54	Sorbus x thuringiaca	Bastard service	0.10	0.10	0.20
55	Quercus hispanica	Lucombe Oak	0.10	0.10	0.20
56	Ulmus hollandica	Elm	0.20	<0.10	0.20
57	Quercus suber	Cork Oak	0.20	<0.10	0.20
58	Aesculus indica	Indian horse chestnut	0.10	0.10	0.20
59	Pterocarya fraxinifolia	Caucasian wingnut	0.10	0.10	0.20
60	Ulmus parvifolia	Chinese elm	0.10	<0.10	0.20
61	Tilia petiolaris	Pendent silver linden	0.10	<0.10	0.20
62	Corylus colurna	Turkish hazelnut	0.10	<0.10	0.20
63	Tilia platyphyllos	Bigleaf lime	0.10	0.10	0.10
64	Zelkova serrata	Japanese zelkova	0.10	<0.10	0.10
65	Platanus orientalis	Oriental plane	<0.10	0.10	0.10
66	Ulmus pumila	Siberian elm	0.10	<0.10	0.10

Appendix II. Species Importance Ranking List

Rank	Scientific Name	Common Name	%Population	% Leaf Area	IV [a]
67	Cornus mas	Cornelian cherry	0.10	<0.10	0.10
68	Betula papyrifera	Paper birch	0.10	<0.10	0.10
69	Sorbus intermedia	Swedish whitebeam	0.10	<0.10	0.10
70	Sorbus torminalis	Wild service tree	0.10	<0.10	0.10
71	Acer negundo	Boxelder	0.10	<0.10	0.10
72	Liriodendron tulipifera	Tulip tree	0.10	<0.10	0.10
73	Taxus baccata	English yew	0.10	<0.10	0.10
74	Acer platanoides 'Crimson King'	Crimson king norway maple	0.10	<0.10	0.10
75	Pinus nigra	Austrian pine	0.10	<0.10	0.10
76	Sorbus aucuparia	European mountain ash	0.10	<0.10	0.10
77	Quercus	Oak spp	0.10	<0.10	0.10
78	Salix	Willow spp	0.10	<0.10	0.10
79	Cedrus	Cedar spp	0.10	<0.10	0.10
80	Robinia	Robinia spp	0.10	<0.10	0.10
81	Juglans nigra	Black walnut	0.10	<0.10	0.10
82	Zelkova carpinifolia	Caucasian zelkova	<0.10	<0.10	0.10
83	Catalpa bignonioides	Southern catalpa	0.10	<0.10	0.10
84	Nothofagus	Nothofagus spp	0.10	<0.10	0.10
85	Cupressus macrocarpa	Monterey cypress	<0.10	<0.10	0.10
86	Acer ginnala	Amur maple	0.10	<0.10	0.10
87	Liriodendron	Tuliptree spp	<0.10	<0.10	0.10
88	Metasequoia glyptostroboides	Dawn redwood	<0.10	<0.10	0.10
89	Eucalyptus	Gum spp	<0.10	<0.10	0.10
90	Ostrya carpinifolia	Hop hornbeam	<0.10	<0.10	0.10
91	Fagus sylvatica 'purpurea'	Copper beech	<0.10	<0.10	0.10
92	Populus tremula	European aspen	<0.10	<0.10	<0.10
93	Cupressocyparis leylandii	Leyland cypress	<0.10	<0.10	<0.10
94	Acer	Maple spp	<0.10	<0.10	<0.10
95	Populus x canescens	Gray poplar	<0.10	<0.10	<0.10
96	Sorbus latifolia	Whitebeam	<0.10	<0.10	<0.10
97	Ulmus glabra	Wych elm	<0.10	<0.10	<0.10
98	Morus nigra	Black mulberry	<0.10	<0.10	<0.10
99	Davidia involucrata	Dove tree	<0.10	<0.10	<0.10

Rank	Scientific Name	Common Name	%Population	% Leaf Area	IV [a]
100	Gleditsia triacanthos	Honeylocust	<0.10	<0.10	<0.10
101	Acer palmatum	Japanese maple	<0.10	<0.10	<0.10
102	Pyrus	Pear spp	<0.10	<0.10	<0.10
103	Prunus cerasifera	Cherry plum	<0.10	<0.10	<0.10
104	Rhus	Sumac spp	<0.10	<0.10	<0.10

Appendix III. Tree values by species

Species	Number of trees	Carbon stored (mt)	Gross Seq (mt/yr)	Leaf Area (Ha)	Leaf Biomass (mt)	Replacement Cost (£)
London Plane	1188	2938.03	51.15	185.88	85.38	£8,636,585.15
Common Lime	324	159.65	5.91	16.47	7.66	£929,131.97
Sweet Chestnut	179	48.92	2.87	4.51	3.16	£185,244.06
English Oak	169	63.03	2.54	3.46	2.31	£196,181.88
Horse chestnut	140	161.96	5.01	8.65	6.05	£378,932.82
Small Leaf Lime	102	17.86	1.17	3.62	2.71	£107,325.06
Silver Birch	76	9.72	0.63	0.94	0.56	£31,232.10
Ash	71	15.95	0.83	2.20	2.34	£71,109.31
Hawthorn	66	3.98	0.35	0.45	0.57	£14,892.60
Norway Maple	56	34.04	1.32	3.26	1.76	£140,626.62
Silver Lime	54	15.82	0.75	3.10	1.44	£97,776.98
Pin Oak	44	19.70	0.91	1.11	1.00	£66,547.34
Turkey Oak	41	47.84	1.64	1.86	1.83	£141,811.88
English Walnut	35	5.14	0.38	1.37	0.58	£18,754.39
plum spp	29	8.44	0.50	0.62	0.48	£24,831.69
Hornbeam	28	5.07	0.35	0.86	0.52	£19,253.02
Beech	28	32.41	0.99	1.86	0.93	£102,068.99
Alder	26	4.37	0.29	0.47	0.35	£16,723.46
Sweet cherry	26	16.16	0.75	0.99	0.77	£53,152.64
Crimean Lime	26	11.77	0.48	1.04	0.48	£71,414.50
Red horsechestnut	25	18.69	0.71	0.92	0.68	£71,864.48
apple spp	24	2.47	0.22	0.34	0.29	£9,719.02
Northern red oak	21	14.47	0.52	0.92	0.74	£49,763.14
Sycamore	18	20.09	0.57	0.93	0.65	£78,924.11
Hedge maple	17	2.24	0.20	0.45	0.26	£ 8,103.40
Silver maple	17	20.36	0.53	1.14	0.60	£ 97,059.71
Italian alder	17	6.16	0.29	0.53	0.38	£ 24,351.17
Holm Oak	14	5.37	0.34	0.39	0.38	£ 18,042.31
Cappadocian maple	13	3.73	0.24	0.49	0.27	£ 15,233.29
White ash	13	6.32	0.27	0.27	0.16	£ 22,472.96
Flowering ash	13	6.76	0.26	0.27	0.19	£ 34,582.43
Poplar spp	13	11.26	0.30	0.62	0.42	£ 40,720.10

Species	Number of trees	Carbon stored (mt)	Gross Seq (mt/yr)	Leaf Area (Ha)	Leaf Biomass (mt)	Replacement Cost (£)
Grey alder	11	1.15	0.10	0.10	0.07	£ 4,309.69
hawthorn spp	11	0.55	0.07	0.04	0.01	£ 1,972.04
White willow	11	19.05	0.60	0.42	0.27	£ 65,284.58
Black poplar	10	4.67	0.22	0.27	0.19	£ 20,658.67
Lombardy poplar	10	4.88	0.23	0.25	0.18	£ 22,299.47
Carolina poplar	9	22.46	0.35	0.93	0.86	£ 69,009.90
Tree of heaven	8	4.73	0.23	0.31	0.23	£ 15,226.62
English holly	8	1.01	0.07	0.09	0.11	£ 3,918.04
Yellow buckeye	7	1.51	0.11	0.20	0.13	£ 5,415.11
Black locust	7	8.10	0.25	0.18	0.10	£ 28,735.38
Indian paper birch	6	1.29	0.08	0.12	0.07	£ 4,293.04
Yellowwood	6	0.09	0.02	0.01	0.01	£ 396.91
Caucasian ash	6	0.48	0.05	0.09	0.06	£ 2,385.33
Sweetgum	6	0.18	0.01	0.06	0.03	£ 1,002.47
Whitebeam	6	2.39	0.10	0.18	0.14	£ 10,002.68
Ginkgo	5	2.14	0.09	0.12	0.05	£ 7,484.57
White poplar	5	1.67	0.07	0.25	0.21	£ 8,166.07
Willow oak	5	0.35	0.03	0.09	0.08	£ 1,845.76
Cork oak	5	0.82	0.07	0.06	0.10	£ 2,941.59
Golden weeping willow	5	2.08	0.13	0.17	0.11	£ 8,549.62
Dutch elm	5	0.63	0.06	0.06	0.04	£ 1,550.45
Indian horse chestnut	4	0.84	0.07	0.13	0.10	£ 2,874.83
Turkish hazelnut	4	1.85	0.08	0.11	0.08	£ 7,628.58
Lucombe oak	4	2.50	0.12	0.14	0.14	£ 7,920.76
Rowan spp	4	2.41	0.10	0.16	0.13	£ 9,327.36
Bastard service tree	4	2.32	0.09	0.16	0.13	£ 9,575.09
Pendent silver lime	4	0.73	0.04	0.11	0.05	£ 4,211.77
Chinese elm	4	0.16	0.02	0.12	0.14	£ 171.34
Siberian elm	4	3.11	0.14	0.28	0.19	£ 5,158.96
Boxelder	3	0.96	0.04	0.05	0.04	£ 4,045.24
Paper birch	3	1.00	0.06	0.06	0.04	£ 3,160.42

Appendix III. Tree values by species

Species	Number of trees	Carbon stored (mt)	Gross Seq (mt/yr)	Leaf Area (Ha)	Leaf Biomass (mt)	Replacement Cost (£)
Cornelian cherry	3	0.63	0.03	0.07	0.05	£ 1,784.03
Tulip tree	3	0.22	0.02	0.05	0.03	£ 765.72
oak spp	3	0.09	0.02	0.01	0.01	£ 286.43
Rowan	3	0.15	0.01	0.01	0.01	£ 674.65
Swedish whitebeam	3	1.16	0.05	0.05	0.04	£ 4,843.38
Wild service tree	3	0.71	0.03	0.05	0.04	£ 3,008.58
English yew	3	0.09	0.01	0.03	0.04	£ 421.61
Large leaf Lime	3	0.32	0.03	0.13	0.08	£ 1,847.53
elm spp	3	0.32	0.03	0.07	0.05	£ 731.05
Japanese zelkova	3	2.20	0.06	0.12	0.09	£ 7,696.83
Amur maple	2	0.19	0.02	0.01	0.01	£ 553.20
Crimson king norway maple	2	0.51	0.04	0.10	0.05	£ 1,875.19
Southern catalpa	2	0.76	0.04	0.03	0.02	£ 2,764.71
Black walnut	2	1.90	0.04	0.05	0.04	£ 6,584.51
nothofagus spp	2	0.05	0.01	0.01	0.01	£ 123.16
Austrian pine	2	1.12	0.04	0.09	0.09	£ 8,550.69
Caucasian wingnut	2	7.25	0.05	0.29	0.23	£ 20,958.65
Robinia spp	2	0.11	0.01	0.06	0.03	£ 203.39
willow spp	2	6.25	0.07	0.07	0.04	£ 19,369.01
redcedar spp	2	0.59	0.04	0.06	0.05	£ 2,224.10
maple spp	1	0.18	0.01	0.03	0.02	£ 603.66
Japanese maple	1	0.53	0.03	0.01	0.01	£2,338.97
Leyland cypress	1	0.10	0.01	0.04	0.05	£459.62
Monterey cypress	1	1.14	0.03	0.09	0.15	£5,624.66
Dove tree	1	0.14	0.01	0.02	0.02	£498.30
gum spp	1	0.27	0.01	0.06	0.08	£689.43
Copper beech	1	1.54	0.03	0.05	0.03	£4,987.61
Honeylocust	1	0.24	0.01	0.02	0.02	£860.81
tuliptree spp	1	0.43	0.03	0.07	0.04	£1,894.97
Dawn redwood	1	0.36	0.02	0.07	0.04	£2,507.80
Black mulberry	1	0.32	0.02	0.03	0.02	£1,218.28

Species	Number of trees	Carbon stored (mt)	Gross Seq (mt/yr)	Leaf Area (Ha)	Leaf Biomass (mt)	Replacement Cost (£)
Hop hornbeam	1	0.22	0.02	0.06	0.04	£900.43
Oriental planetree	1	3.09	0.09	0.25	0.12	£9,589.93
Grey poplar	1	0.44	0.01	0.03	0.02	£2,230.52
European aspen	1	0.26	0.02	0.04	0.03	£1,357.15
Cherry plum	1	1.17	0.03	0.01	0.01	£2,581.45
pear spp	1	0.14	0.01	0.01	0.01	£540.87
sumac spp	1	0.08	0.01	0.01	0.00	£251.59
Broadleaf whitebeam	1	0.92	0.02	0.03	0.03	£3,549.13
Wych elm	1	0.01	0.00	0.03	0.02	£24.75
Caucacian zelkova	1	1.42	0.06	0.12	0.09	£4,558.40
Totals	**3174**	**3871.51**	**88.10**	**257.72**	**131.80**	**£12,246,489.67**

Appendix IV. Notes on Methodology

i-Tree Eco is designed to use standardised field data from randomly located plots or complete inventories 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).
- Total carbon stored and net carbon annually sequestered by trees.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants.
- 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 Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

All the trees in Hyde park were measure as a complete inventory. All field data was collected during the leaf-on season to properly assess tree canopies. 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 O2 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.

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 [52, 53, and 54].

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. 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 that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere. 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. CAVAT valuation is based on the public amenity using the functionality and location of trees to provide an amenity value.

For a full review of the model see UFORE (2010) and Nowak and Crane (2000).

For UK implementation see Rogers et al (2012).

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