i-Tree Eco Inventory Report

Welwyn Hatfield Borough Council Trees Excluding Hertfordshire County Council Trees.

December 2019

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This assessment was carried out by Treeconomics

Executive Summary

In this report, the trees and woodlands managed by Welwyn Hatfield Borough Council have been assessed based on the benefits they provide to society. These trees, which form part of Welwyn Hatfield's natural capital, are generally recognised and appreciated for their amenity, presence and stature in the townscape and surroundings. However, society is often unaware of the many other benefits (or ecosystem services) that trees provide to those living in our towns and cities.

The trees in and around our urban areas (together with woodlands, shrubs, hedges, open grass, green space and wetland) are collectively known as the 'urban forest'. This urban forest improves our air, protects watercourses, saves energy, and improves economic sustainability[1]. There are also many health and well-being benefits associated with being in close proximity to trees and there is a growing research base to support this[2] .

Welwyn Hatfield's publicly managed trees are a crucial part of the town's urban forest, rural areas and woodlands. Many of the benefits that Welwyn Hatfield's urban forest provides are offered through its public trees.

Economic valuation of the benefits provided by our natural capital[3] (including the urban forest) can help to mitigate for development impacts, inform land use changes 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. Yet, as the benefits provided by such natural capital are often poorly understood, they are often undervalued in the decision-making process.

In order to produce values for some of the benefits provided by Welwyn Hatfield's publicly managed trees, a state of the art, peer reviewed software system called i-Tree Eco[4] (referred to as 'Eco' throughout the report) was used.
This is a partial analysis as not all trees or ecosystem services were quantified or valued. Therefore the figures presented in this report should be regarded as a conservative estimate.

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1 Doick et al (2016)

2 http://depts.washington.edu/hhwb/

3 Natural capital can be defined as the world's stocks of natural assets which include geology, soil, air, water, trees and all living things

4 i-Tree Eco is i-Tree is a suite of open source, peer-reviewed and continuously improved software tools developed by the USDA Forest Service and 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. It is designed to use complete or sample plot inventories 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.
I-Tree Eco is adaptable to multiple scales from a single tree to area-wide assessments.
For more information see www.itreetools.org

Highlights Include:

- **The street trees managed by Welwyn Hatfield Borough Council remove 3.5 tonnes of air-borne pollutants each year and store over 9,150 tonnes of carbon.**

- **The street trees divert over 6,700 cubic meters of storm water runoff away from the local sewer systems each year. This is worth an estimated £10,200 each year in avoided stormwater treatment costs.**

- **Welwyn Hatfield's woodlands remove an estimated 27.5 tonnes of air-borne pollutants with a value of over £172,000 and sequester more than 2100 tonnes of Carbon each year.**

- **The total replacement cost of all street trees in Welwyn Hatfield currently stands at £27,432,952.**

Welwyn Hatfield Public Tree Inventory - Headline Figures		
Number of Street Trees Measured	16,922	
Number of Woodland Trees Measured	100,500	
Total Number of Trees Measured	117,422	
Most Common Street Tree Species	Quercus robur, Prunus, Betula pendula	
Replacement Cost	£27,432,952	
Species Recorded	237	
Amounts and Values - Street Trees		
Pollution Removal	3.5 tonnes	£35,669
Carbon Storage	9,157 tonnes	£2,249,646
Carbon Sequestration	237 tonnes	£58,122
Avoided Runoff	6,734m³	£10,210
Total Annual Benefits	**£104,001**	
Amounts and Values - Woodlands		
Pollution Removal	27.5 tonnes	£172,197
Carbon Storage	68,572 tonnes	£16,847,552
Carbon Sequestration	2147 tonnes	£527,594
Avoided Runoff	46,188 m³	£70,039
Total Annual Benefits	**£769,830**	

Table 1: Headline figures

Total Number of Trees Measured: Not all records supplied were used in the analysis. For further details see the methodology section below.
Leaf Area: The area of ground covered by leaves when viewed from above (not to be confused with Leaf Area Index (LAI) which is the total surface area of leaves). This is not the total canopy cover for Welwyn Hatfield as only the council inventoried trees are included in the analysis and some tree canopy dimensions were conservatively estimated.
Capital Asset Value for Amenity Trees (CAVAT): A valuation method developed in the UK to express a tree's relative contribution to public amenity and its prominence in the urban landscape.
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 CO_2e and the DECC figures of £67 per metric ton for 2019.
Pollution removal: This value is calculated based on the UK social damage costs for 'Transport Urban Medium' and the US externality prices where UK figures are not available; £0.98 per Kg (carbon monoxide - USEC), £1.25 per kg (ozone - USEC), £10.84 per Kg (nitrogen dioxide - UKSDC), £6.27 per Kg (sulphur dioxide - UKSDC), £203.36 per Kg (particulate matter less than 2.5 microns - UKSDC). Values calculated using an exchange rate of $0.75 = £1.00.
Avoided Runoff: Based on the amount of water held in the tree canopy and re-evaporated after the rainfall event. The value is calculated using an average volumetric charge of £1.516 per cubic metre. It includes the cost of the avoided energy and associated greenhouse gas emissions in treating the water.

Data processed using i-Tree Eco Version 6.0.16.

Methodology

Welwyn Hatfield Borough Council's tree inventory currently holds the records for 29,746 urban street trees, of which 12,000 are Hertfordshire County Council: Highways' trees. These highway trees are not included in the dataset used by Eco to produce this study.

Taking into account a handful of trees recorded in groups, 65 individual tree records have been added to the tally. The minimum data required by Eco is tree species and diameter at breast height, dbh, and as 889 records fail to note both facts, these records are not included in the study. The more data that is available for each tree, the more accurate the outputs will be. However, the Eco software requires data to be a greater value than 0 for all the structural data of each tree. Where required, estimates were made based on the information available.

With regard to the extensive woodlands owned by Welwyn Hatfield Borough Council, the hectarage of the two largest woodlands, Sherrardspark Wood and Northaw Great Wood has been used alongside a density value of 500 and an average dbh of 45cms, to calculate the likely number of trees in both woodlands. For these woodlands, an average mix of oak, hornbeam and birch was considered most appropriate. There are more woodlands in the borough, but these have not been included in the data set to compensate for the large glades and rides in Northaw Great Wood and Sherrardspark Wood. This leads to the premise that the values presented are likely to be very conservative estimates.
The only Welwyn Hatfield Borough Council trees not included in this study are those growing in the gardens of council owned housing properties. No privately owned trees in borough are included.

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 PM2.5. % of total air pollution removed by trees. Current Carbon storage. Carbon sequestered. Stormwater Attenuation (Avoided Runoff) i-Tree eco also calculates Oxygen production but this service is not valued.
Structural and Functional values	Replacement Cost in £. Carbon storage value in £. Carbon sequestration value in £. Pollution removal value in £. Avoided runoff in £

Table 2: Study Outputs.

For each category the top ten performing species (based on the trees' performance rather than their quantity or size) were used for charts and tables within this report. However, all other figures for the remaining 227 species are available within the Eco files for this project. For a more detailed description of the model calculations see Appendix IV.

Tree Characteristics

Tree Species

Welwyn Hatfield's council street tree inventory has a very high diversity of species (237). The most common tree species, with 11.2% of the 16,922 trees in the Welwyn Hatfield tree inventory is Cherry (*Prunus*). The second, third and fourth most common trees are respectively: Silver Birch (*Betula pendula* - 6.7%), Apple (*Malus* - 6.0%) and Norway maple (*Acer platanoides* - 4.9%).
Appendix II contains a full list of species included in the inventory.

Calculations of Welwyn Hatfield's woodland trees are based on a species mix of Oak, Hornbeam, and Birch. Therefore, it would not be appropriate to analyse these trees as part of this diversity chapter.

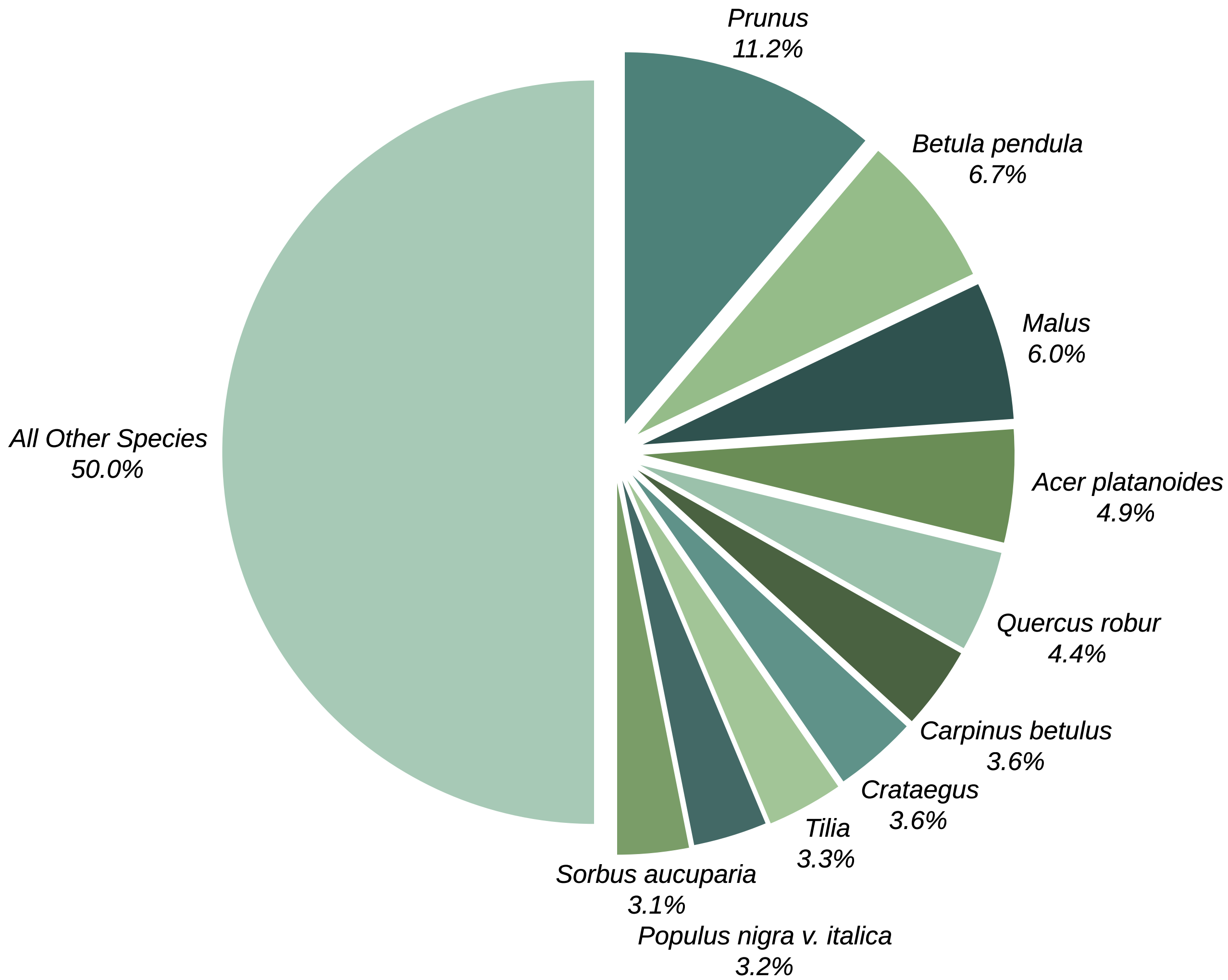

Figure 1: Percentage Population of Tree Species

Tree Diversity

Tree diversity is an important aspect of the tree population to take into account. Tree diversity increases overall resilience in the face of various environmental stress-inducing factors. Diversity includes both the individual diversity within a tree species (i.e. genetic diversity) and between different tree species in terms of different genera or families (e.g. Acer (maple family); Fraxinus (Ash family)).

Tree species which originate from more distant regions to each other may be more genetically dissimilar, their presence may therefore increase resilience to environmental perturbations. A more diverse tree-scape is better able to deal with possible changes in climate or potential pest and disease impacts. This is because with more diverse tree populations the likelihood that they all will be vulnerable to a particular threat is lower and therefore a smaller proportion will be detrimentally affected. The tree population within Welwyn Hatfield’s street tree inventory represents a rich community of trees given the area, with 237 species identified. However, some of the inventory records provided are at the genus level only, indicating that species richness may actually be greater than the 237 species provided.

Tree species from 5 continents are represented in Welwyn Hatfield's street tree inventory. Most of the species are native to Europe and Asia (see Figure 2 below). However, further work would be required to assess the condition, size and populations of these trees and to provide recommendations on the best species to choose for any future plantings.

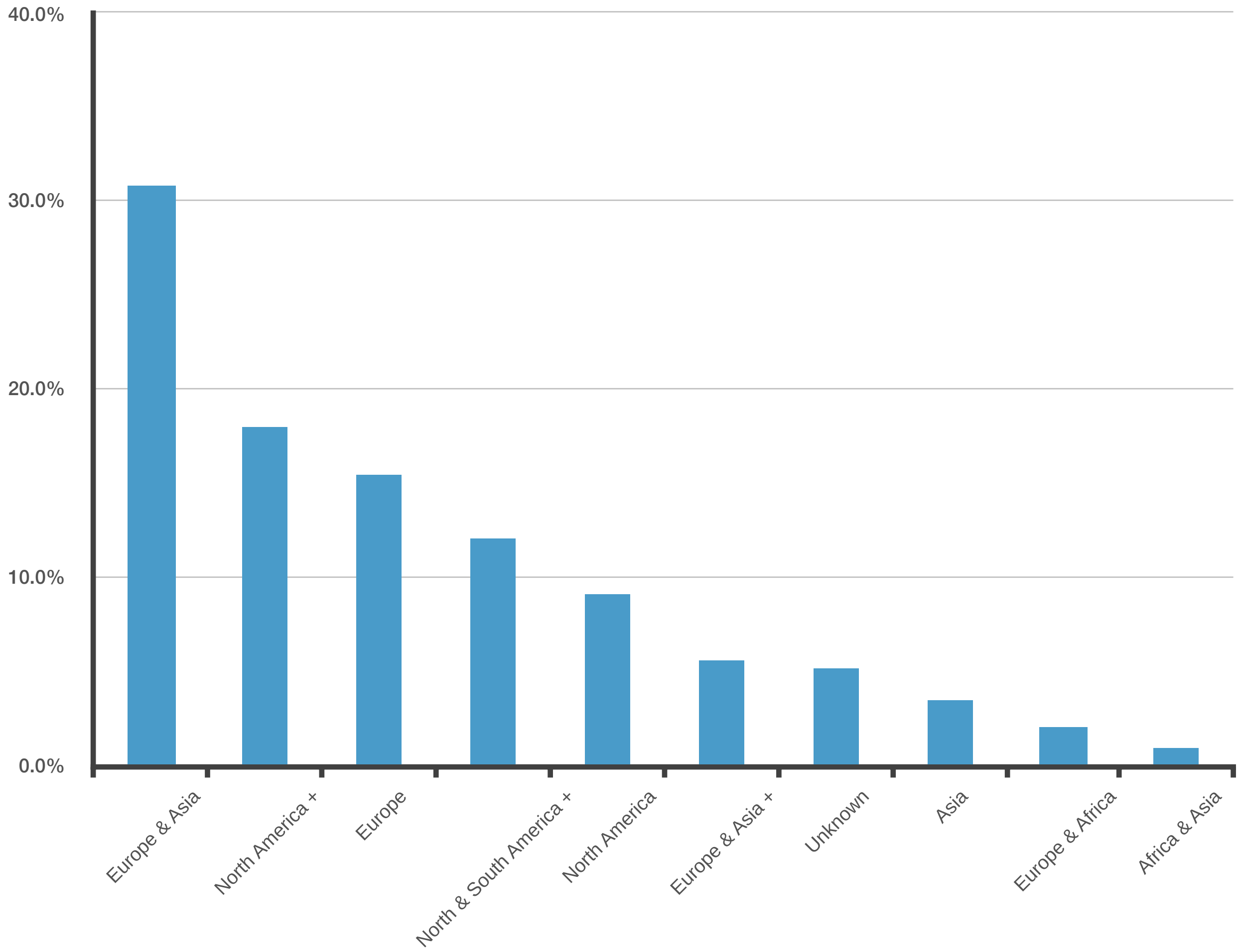

Figure 2: Origin of Tree Species

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

Size Distribution

Size class distribution is also an important aspect to consider in managing a sustainable and diverse 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 inventory, street trees were sized by their stem diameter at breast height (dbh) at 1.3m. Figure 3 (below) shows the percentage of tree population for the ten most common street trees by dbh class.

The chart below represents a fairly typical size class distribution for an urban area, displaying a negative correlation (with percentage composition declining as size increases). There is, however, some variation between species and its worth noting that some of the species are small in stature and are expected to tail off at the larger dbh classes. If new plantings are made up of these smaller stature species there will be a decreasing proportion of larger trees in the future. To maintain or increase canopy cover and tree benefits at or above current levels, more trees capable of attaining a larger size will need to be planted and maintained.

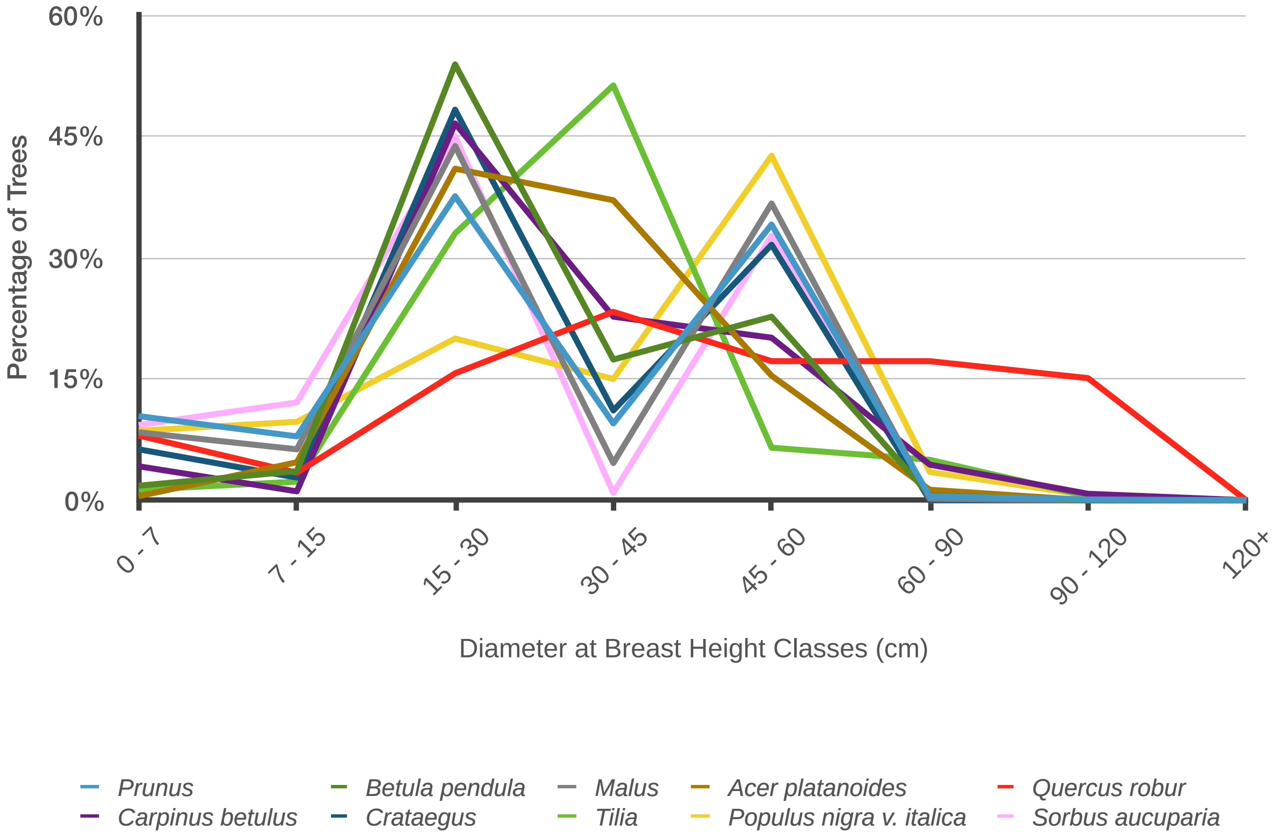

Figure 3: Percentage of Street Tree Population by DBH Class

Leaf Area and Population

Leaf area is an important metric because the total photosynthetic area of a tree's canopy is directly related to the amount of benefit provided. The larger the canopy's surface area, the greater the proportion of air pollution or rainfall will be intercepted.

Within Welwyn Hatfield's street tree inventory, total leaf area is estimated at 3,736,000m². If all the layers of leaves within the tree canopies were spread out, they would cover an area over 7 times the size of Stanborough Park.

The three most dominant street tree species in terms of leaf area are *Prunus* (which has 10% of the total leaf area for all trees), *Quercus robur* (8.0%) and *Acer platanoides* (7.0%).

Figure 4 (below) shows the top ten dominant trees' contributions to total leaf area. In total these ten species, representing 47% of the street tree population, contribute almost 52% of the total leaf area.

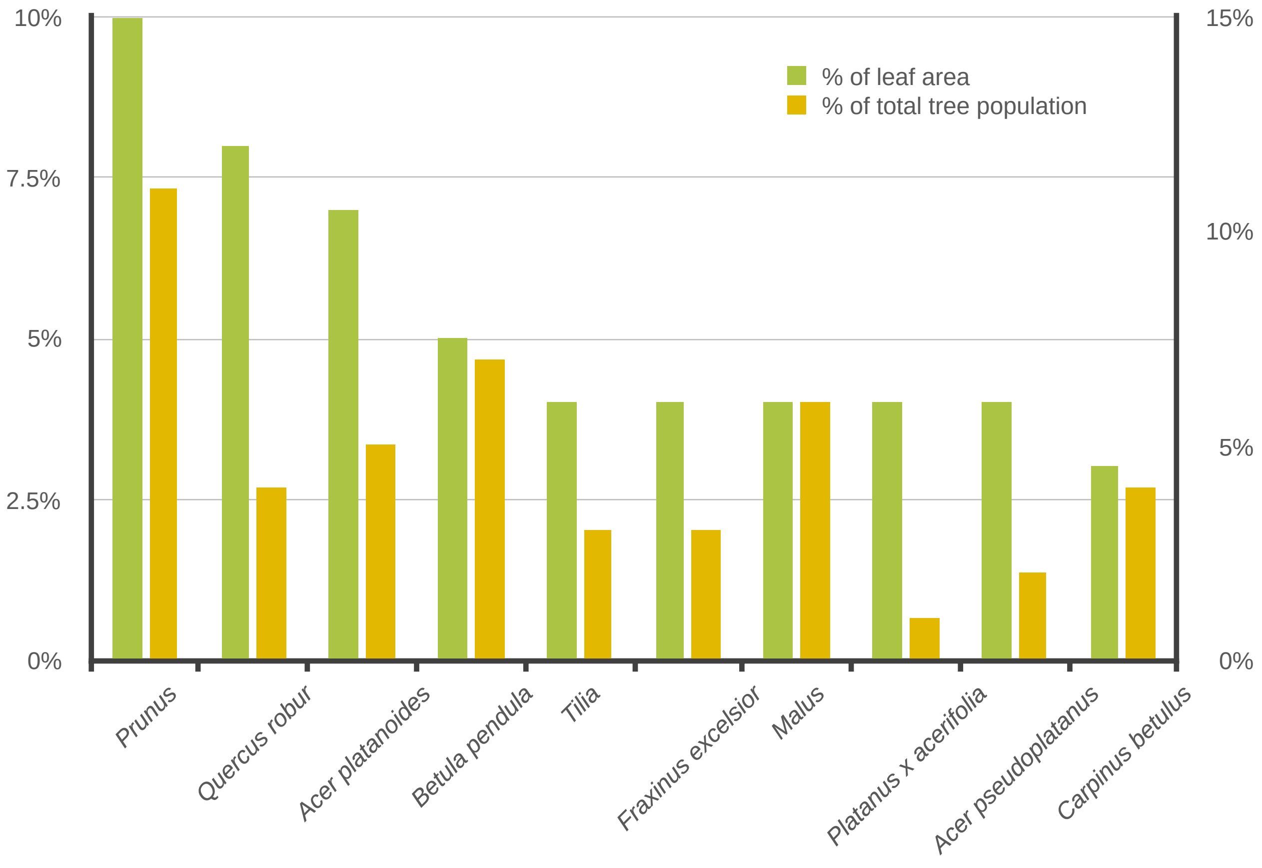

Figure 4: Percentage Leaf Area and Population of the Ten Most Dominant Street Trees

Results - Street Tree and Woodlands Ecosystem Services Resource

Air Pollution Removal

Poor air quality is a common problem in many urban areas, particularly along the road network. Air pollution caused by human activity has become a problem since the beginning of the industrial revolution. With the increase in population and industrialisation, 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 severe health problems in humans to damage to buildings.

Urban trees can help to improve air quality by reducing air temperature and directly removing pollutants[5]. Trees intercept and absorb airborne pollutants on the leaf surface[6]. In addition, by removing pollution from the atmosphere, trees reduce the risks of respiratory disease and asthma, thereby contributing to reduced health care costs[7].

Trees emit volatile organic compounds (VOCs) that can contribute to low-level ozone formation which is detrimental to human health. However, integrated studies have revealed that an increase in tree cover leads to a general reduction in ozone through a reduction in air temperature. Eco accounts for both reduction of ozone and production of VOCs within its algorithms and, as shown in Figures 5 and 6, Eco estimated that the inventoried trees in Welwyn Hatfield remove more ozone than they produce.

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5 Tiwary et al., 2009

6 Nowak et al., 2000

7 Peachey et al., 2009. Lovasi et al., 2008

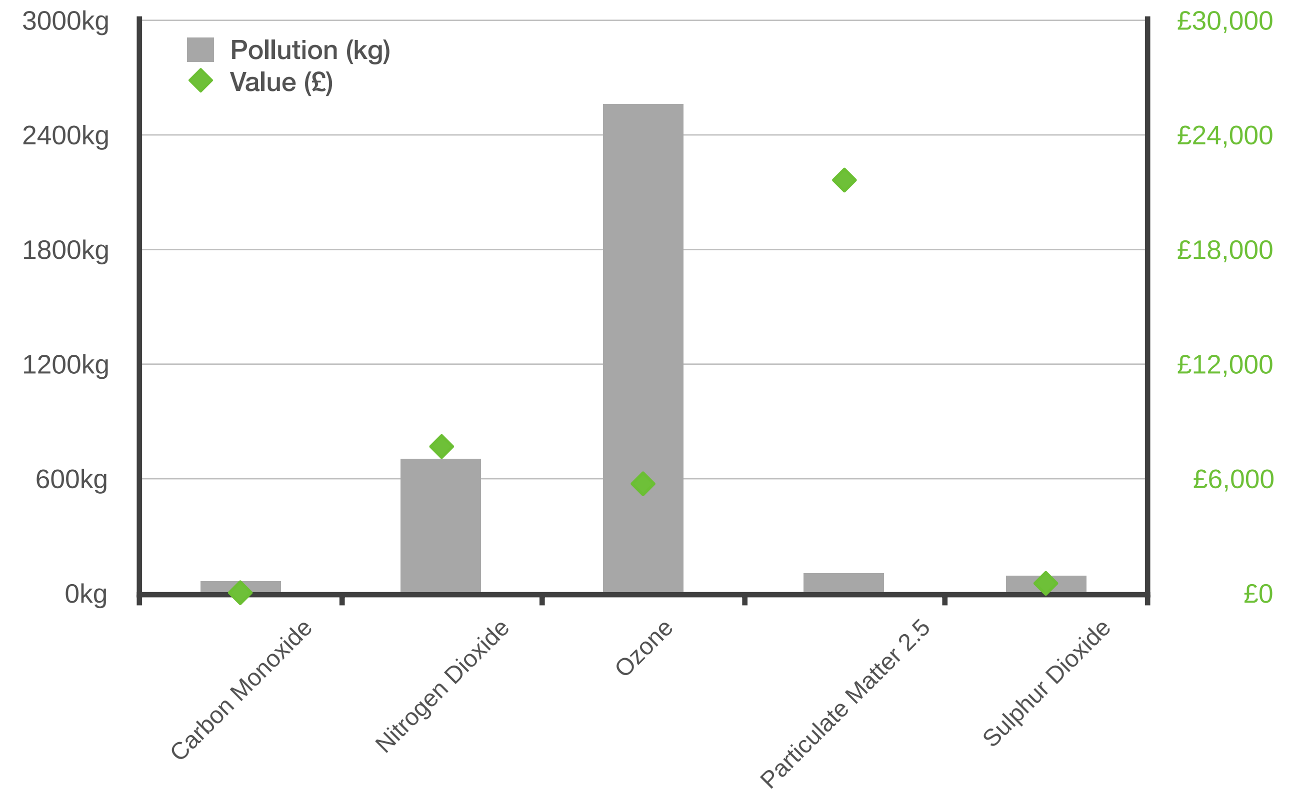

Figure 5: Value of Pollutants Removed and Quantity Per-Annum of Welwyn Hatfield's Street Trees.

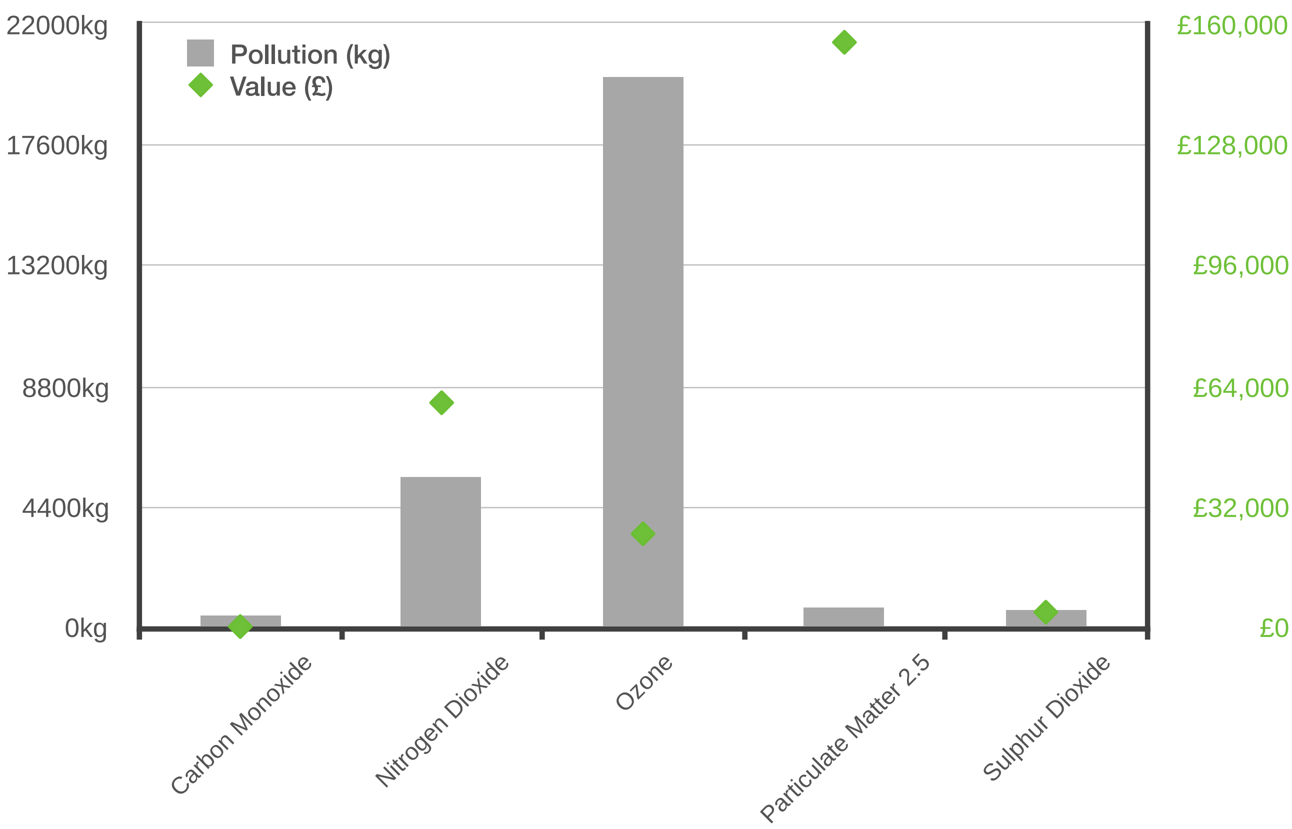

Figure 6: Value of Pollutants Removed and Quantity Per-Annum of Welwyn Hatfield's Woodland Trees.

Valuation of pollutant removal uses UK social damage costs (UKSDC) (where there are no UK figures, US externality costs (USEC) are used in substitution). Greater tree cover, pollution concentrations and leaf area are the main factors influencing pollution filtration. Therefore, increasing areas of tree planting has been shown to further improve air quality. Furthermore, because filtering capacity is closely linked to leaf area it is generally the trees with larger canopy potential that provide the most benefits.

Figure 7 (below) shows the breakdown for the top ten pollution-removing street tree species in Welwyn Hatfield's street tree inventory. As different species can capture different sizes of particulate matter,[8] it is recommended that a broad range of species should be considered for planting in any air quality strategy.

It is interesting to note that despite being the 3rd most common species, '*Malus*' is 7th in the top ten species for air pollution removal. This is likely due to its generally smaller size and leaf area. This illustrates how large trees provide more benefits than smaller specimens. To highlight this, *Platanus x acerifolia*, a particularly large-leaved species, is not in the top ten by percentage composition (it is 19th, with 1.6%) but it is 9th for pollution removal.

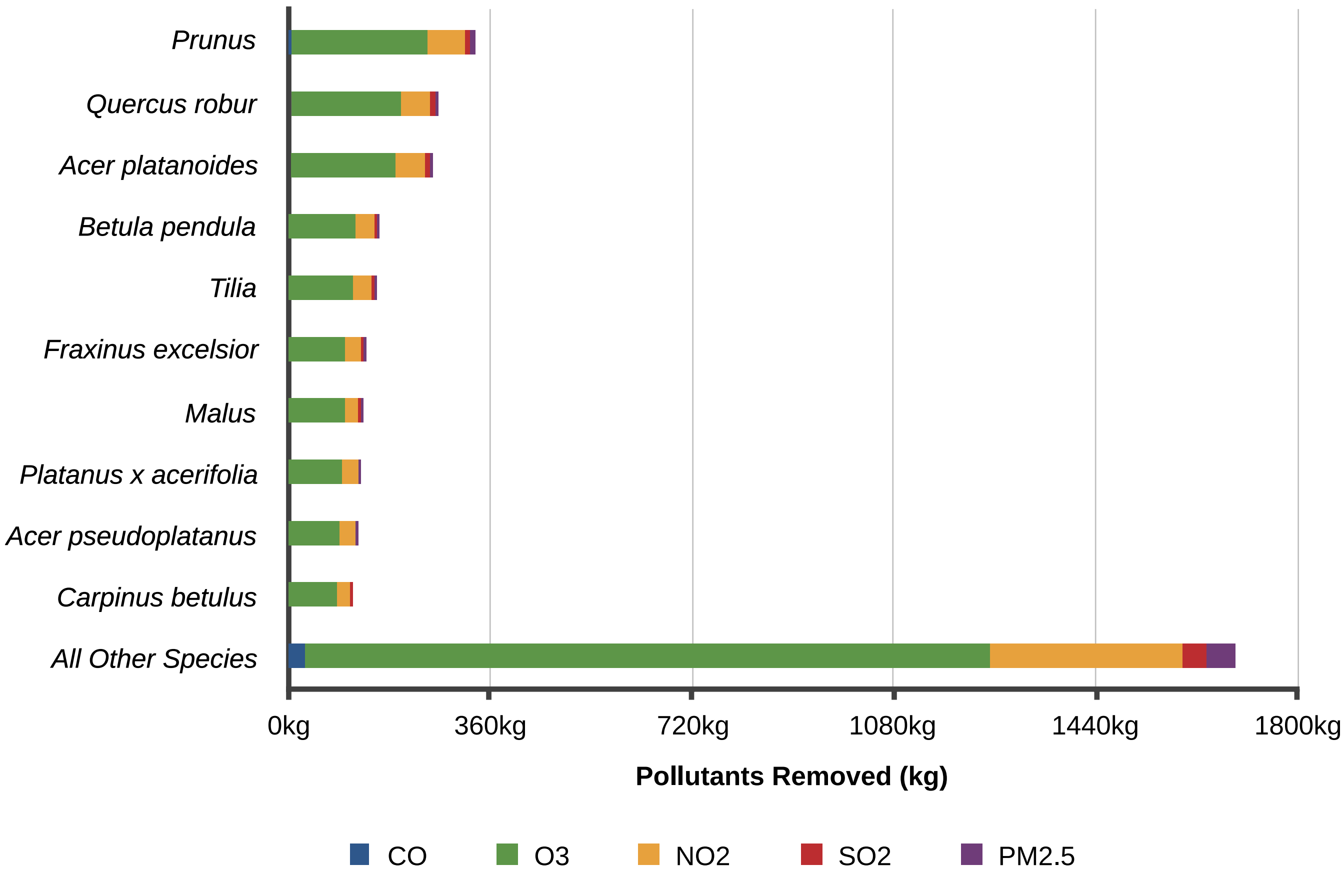

Figure 7: Pollution Removal by Tree Species

8 Freer-Smith et al. 2005

Carbon Storage and Sequestration

The main driving force behind climate change is the concentration of carbon dioxide (CO_2) in the atmosphere. Trees can help to 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 to several tonnes of carbon for decades or even centuries[9].

Overall, the trees in the Welwyn Hatfield street tree inventory and woodlands store an estimated 77,729 tonnes of carbon with a value of £19.1 million.

Figure 8 (below) illustrates the carbon storage of the top ten street tree species. As can be seen from the chart, *Quercus robur* stores the greatest amount of carbon, totalling 1,437 tonnes.

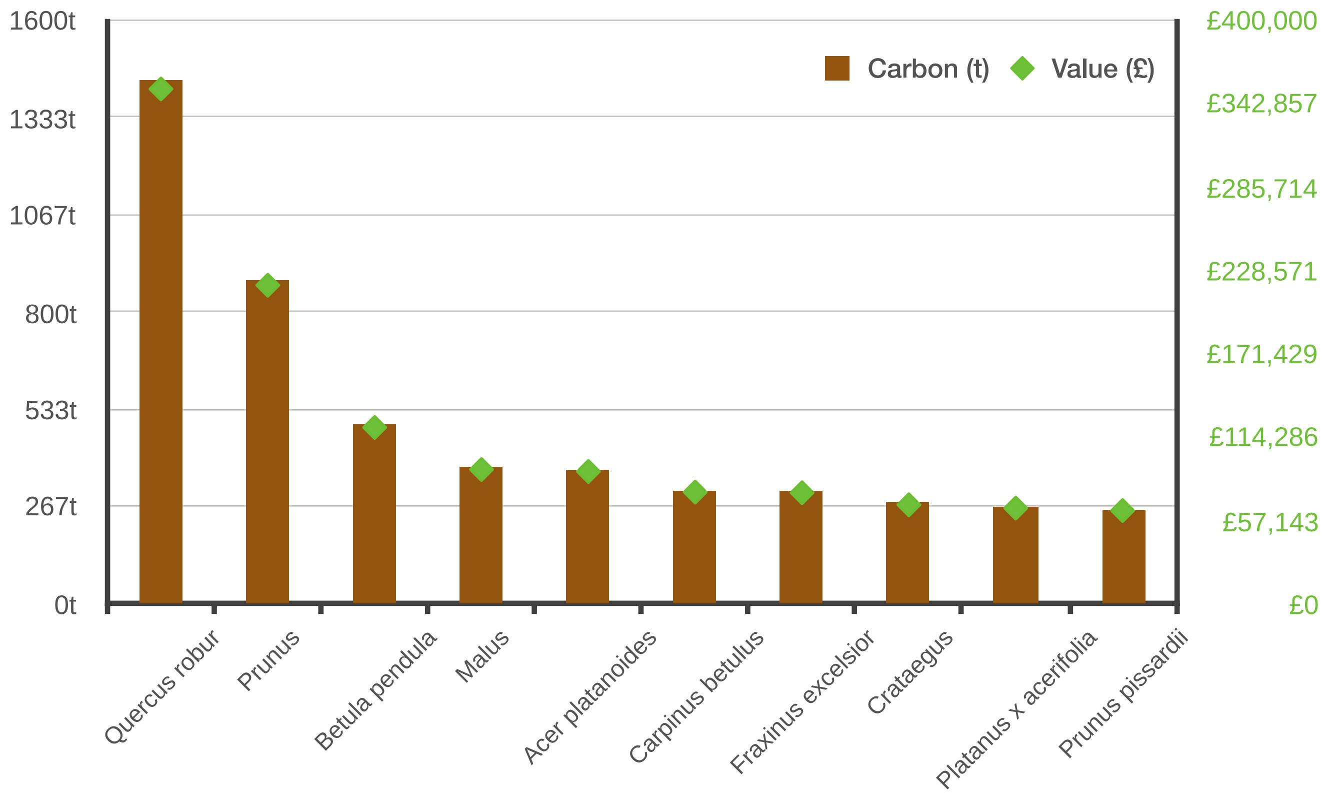

Figure 8: Carbon Storage (tonnes) for Top Ten Street Tree Species in Welwyn Hatfield

[9] Kuhns 2008, Mcpherson 2007

The woodland trees in the Welwyn Hatfield tree inventory store an estimated 68,000 tonnes of carbon with a value of over £16.8 million.

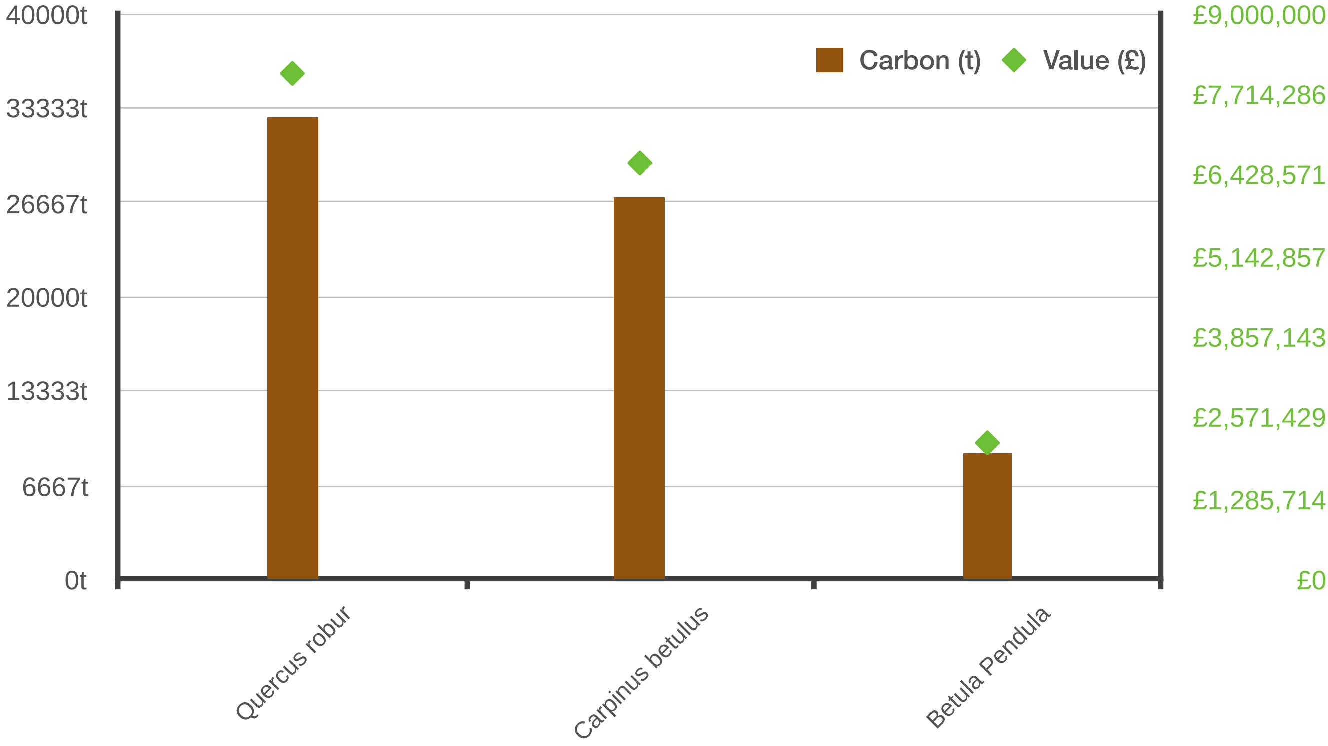

Figure 9: Carbon Storage (tonnes) for the Woodland Tree Species in Welwyn Hatfield

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.

Carbon sequestration is calculated from the predicted growth of trees based on field measurements of individual trees, climate data and genera specific growth rates within Eco. This provides a measure of tree growth (converted volume). The volume is converted into tonnes of carbon based on species specific conversion factors. Following this, the volume is converted to CO_2 equivalent before being multiplied by the unit cost for carbon. The current (2019) UK social cost for carbon is £67/tonne.

Welwyn Hatfield's street inventory trees sequester an estimated 237 tonnes of carbon per year, with a value of £58,122. Table 3 (below) shows Welwyn Hatfield's top ten street trees in terms of carbon sequestration (annually) and the value of the benefit derived from the sequestration of this atmospheric carbon.

Species	Carbon Sequestration (tonnes/yr)	CO^2 Equivalent (Tonnes/yr)	Carbon Sequestration (£/yr)
Prunus	28.37	104.02	£6,969
Quercus robur	18.83	69.04	£4,626
Betula pendula	17.01	62.37	£4,179
Malus	12.36	45.32	£3,036
Acer platanoides	11.25	41.24	£2,763
Carpinus betulus	8.80	32.27	£2,162
Crataegus	8.67	31.79	£2,130
Prunus pissardii	8.40	30.79	£2,063
Populus nigra v. italica	7.22	26.49	£1,775
Fraxinus excelsior	7.09	25.99	£1,741
All Other Species	108.57	398.17	26678
Total	236.57	867.49	£58,122

Table 3: Top Ten Street Tree Carbon Sequestration by Species

Of the street tree species inventoried, *Prunus* sequesters the most carbon, adding approximately 28 tonnes in the study year to the current *Prunus* carbon storage of 889 tonnes.

Welwyn Hatfield's woodland inventory trees sequester an estimated 2,147 tonnes of carbon per year, with a value of over £527,000. Table 4 (below) shows Welwyn Hatfield's top ten woodland trees in terms of carbon sequestration (annually), and the value of the benefit derived from the sequestration of this atmospheric carbon.

For comparison, the average newly registered car in the UK produces 34.3g carbon per km[10]. Carbon sequestration in Welwyn Hatfield's tree inventory and woodlands therefore corresponds to around 69,503,790 new vehicle km per year, equivalent to 1,328 people driving a car over 10 years[11].

Species	Carbon Sequestration (tonnes/yr)	CO^2 Equivalent (Tonnes/yr)	Carbon Sequestration (£/yr)
Betula pendula	279.91	1026.43	£68,770.81
Carpinus betulus	835.57	3064.04	£205,290.68
Quercus robur	1031.93	3784.07	£253,532.69
Total	2147.41	7874.54	£527,594.18

Table 4: Woodland Top Three Carbon Sequestration by Species

10 http://naei.beis.gov.uk/data/emission-factors
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/454981/veh0150.csv/preview

11 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/823068/national-travel-survey-2018.pdf

Hydrology (Avoided Runoff)

Surface runoff can be a cause for concern in many areas as it can contribute to flooding and is a source of pollution in streams, wetlands, waterways, lakes and oceans. During precipitation events, a proportion of the precipitation is intercepted by vegetation (trees and shrubs) while the remainder reaches the ground. Precipitation that reaches the ground and does not infiltrate the soil becomes surface runoff[12].

In urban areas, large expanses of impervious surfaces increase the volume of runoff. However, trees are very effective at reducing surface runoff[13]. The trees' canopy intercepts precipitation, while the root system promotes infiltration and storage of water in the soil.

Annual avoided surface runoff in Eco is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. The trees within Welwyn Hatfield's street tree inventory reduce runoff by an estimated 6,734m³ a year with an associated value of £10,210.

Figure 10 (below) shows the volumes and values for the ten most important species for reducing runoff.

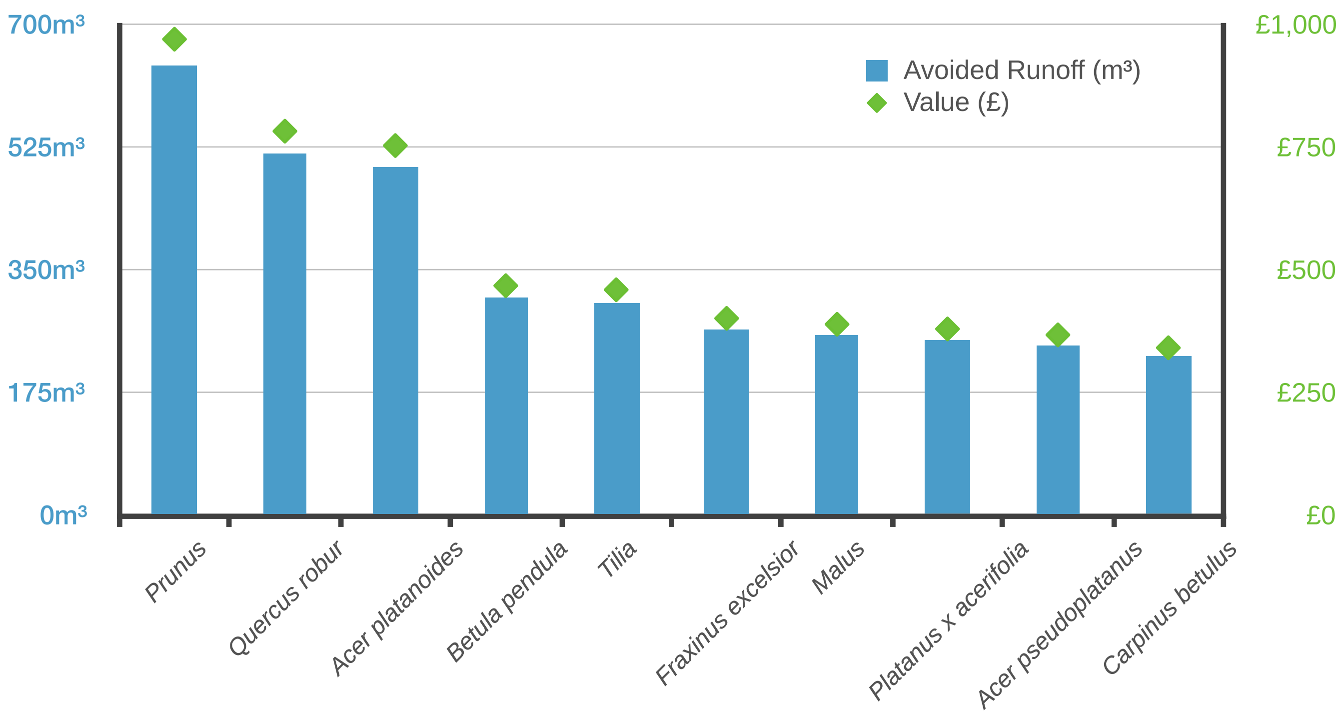

Figure 10: Avoided Runoff by Top Ten Street Tree Species

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12 Hirabayashi 2012

13 Trees in Hard Landscapes (TDAG) 2014

6,734m³ is equivalent to nearly 3 Olympic swimming pools of stormwater being averted every single year.

The trees in Welwyn Hatfield's street tree inventory and woodlands play an important role in reducing runoff: *Prunus* intercepts the largest proportion of precipitation for a species, and is the most important species in this category. This is due to the trees' high population within this inventory.

The trees within Welwyn Hatfield's woodland tree inventory reduce runoff by an estimated 48,188 m³ a year with an associated value of over £70,000.

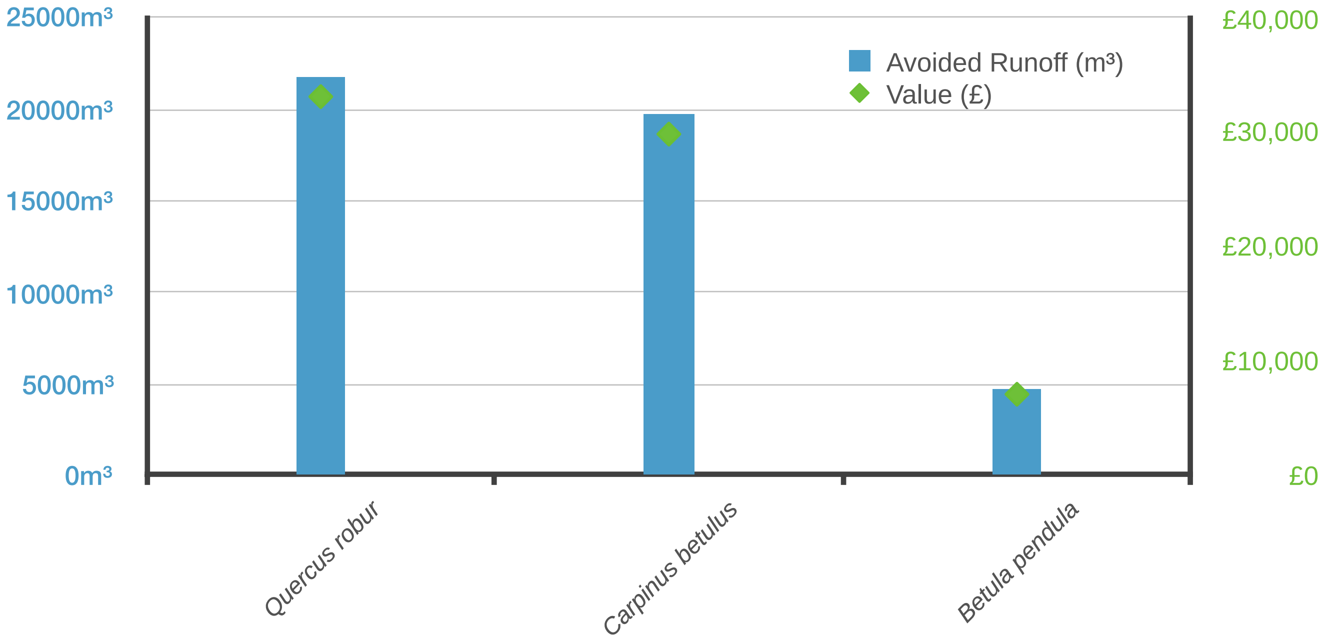

Figure 11: Avoided Runoff by Welwyn Hatfield's Woodland Tree Species

Potential Pests and Diseases

Various pests and diseases can affect trees, reducing both their health and value, and therefore the sustainability of our urban forests. As most pests generally tend to have a specific range of tree hosts, the potential damage that can be caused by each pest will differ.

In this instance Ash dieback (*Hymenoscyphus fraxineus*) and Asian Long Horn Beetle (*ALB - a wood boring insect)* have been selected to illustrate how the results from this survey can be used to estimate the potential impacts on the trees in Welwyn Hatfield.

Ash dieback (*Hymenoscyphus fraxineus*) is harmless in its native range in Asia, associating with native ash species including *Fraxinus mandshurica*. However, European ash (*Fraxinus excelsior*) has shown to be highly susceptible to the pathogenicity of *H fraxineus*.
Fraxinus spp currently account for 4.9% of the Welwyn Hatfield street tree population (or 1,417 trees). Ash trees can be large in stature and, within Welwyn Hatfield, provide many ecosystem service benefits. Therefore their replacement, should they perish, would be costly.

For the purpose of this study, all species of Ash including *Fraxinus Excelsior, Fraxinus Excelsior 'Pendula', Fraxinus Augustifolia 'Raywood', Fraxinus Ornus, Fraxinus americana, 'Autumn Purple', Fraxinus Oxycarpa, Fraxinus velutina* and *Fraxinus Pennsylvanica* have been included. According to the Defra Management Plan for Chalara (Ash Dieback) many species of Ash can be infected but the intensity and appearance of symptoms vary. Common Ash (*Fraxinus Excelsior)* is the most severely affected[14]. This information should be considered when reviewing the impacts of Ash Dieback on Welwyn Hatfield's trees.

These pathogens have the potential to reduce the performance of, or even potentially kill, a number of trees that are present in Welwyn Hatfield's street tree population. Figure 12 (below) illustrates the potential impact of these pathogens, the potential percentage of population that could become infected and those which are resistant.

[14] Defra, 2013

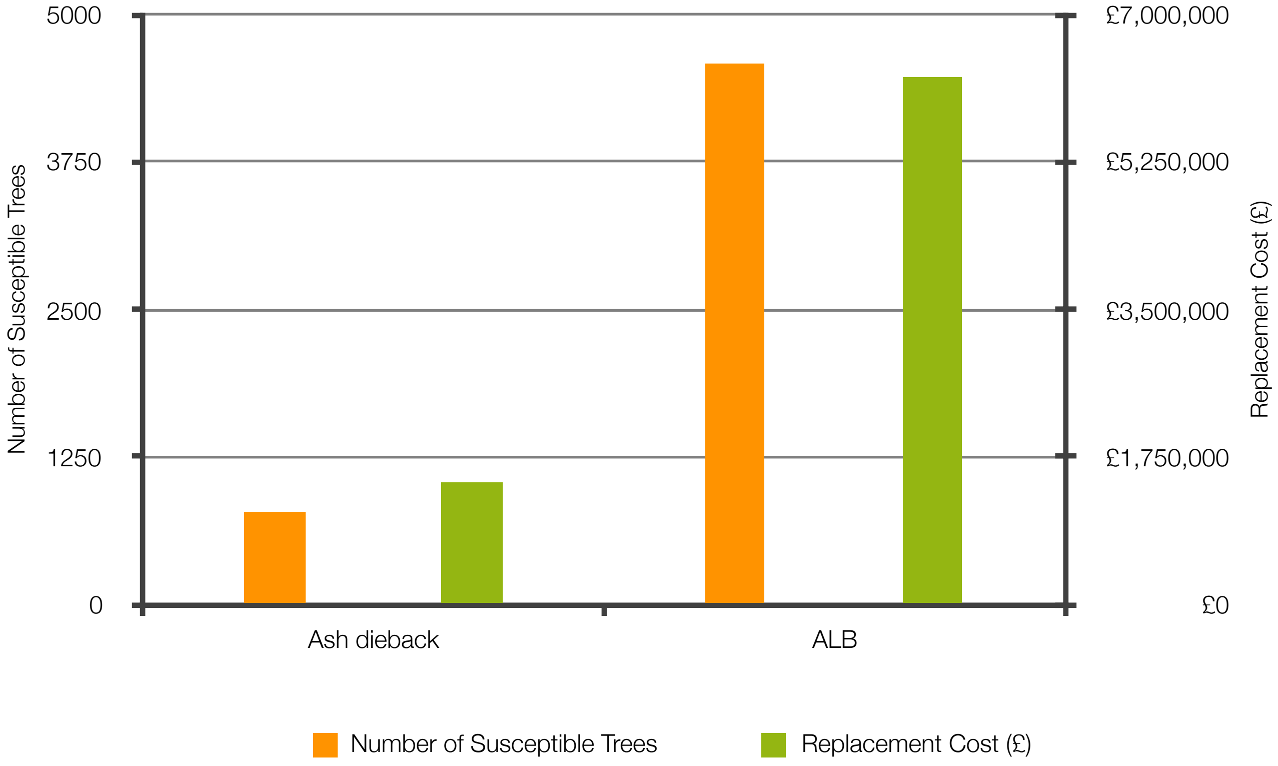

Figure 12: Potential Pest Impacts on Street Tree Species

Asian Long Horn Beetle is an insect that bores into the wood of a wide range of hardwood tree species, sometimes causing the collapse and mortality of parts of the host tree. This beetle could affect around 27% (or 4577) of the trees in the Welwyn Hatfield inventory, including the Sycamore (Acer pseudoplatanus), which makes up around 2.3% of the tree population.

This beetle has been found in the south east of England and originates from Asia. If the beetle were to become established in Britain, there is likely to be extensive damage to both urban and woodland/ forest trees.

Replacement Cost

In addition to estimating the environmental benefits provided by trees, Eco 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[15].

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 13 (below).

The total value of all street trees in the study area, as estimated by Eco, currently stands at over £27.4 million. Oak (*Quercus robur*) is the most valuable species of tree, on account of both its size and population, followed by Prunus (*Prunus*) and Silver birch (*Betula pendula*). These three species (or genera) account for £6.89 million (25%) of the total replacement cost of the trees in Welwyn Hatfield's street tree inventory, with the Oak alone accounting for 12% of the total replacement cost.

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

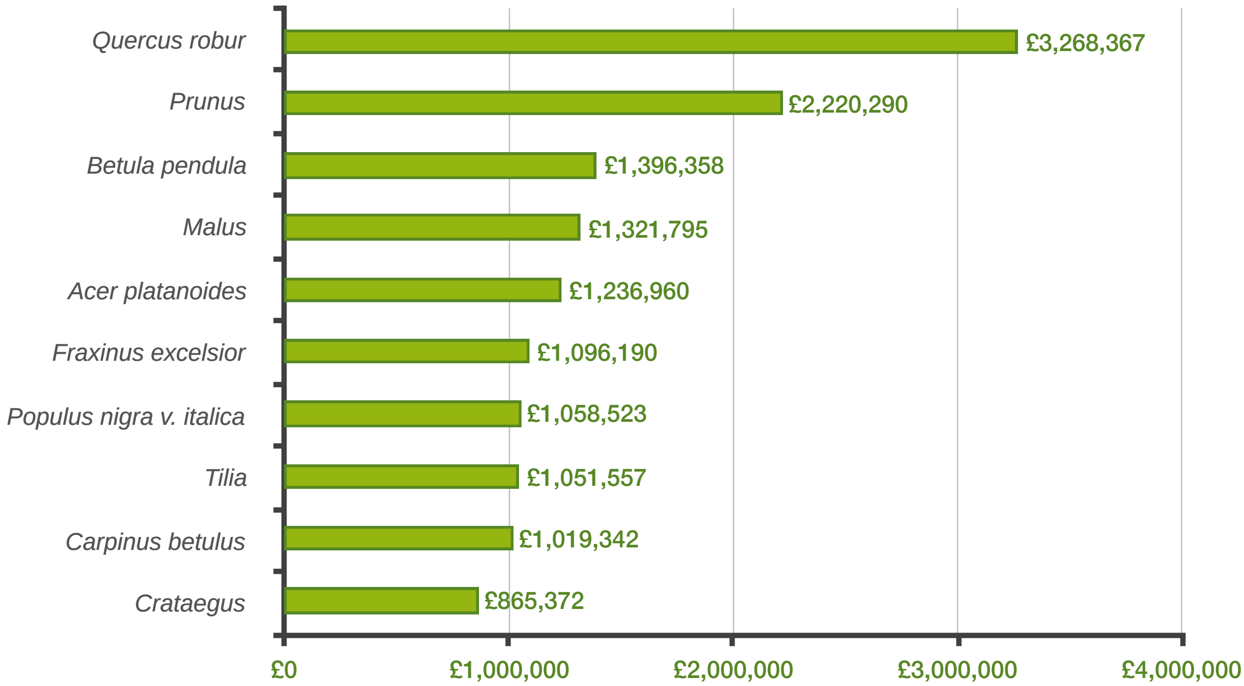

Figure 13: Replacement Cost for Top Ten Trees in Welwyn Hatfield

15 Hollis, 2007

The replacement cost for the woodland areas must be treated as a very conservative estimate as it is based on an average species mix, alongside a density value, rather than full inventory records. The total value of the trees in Sherrardspark Wood and Northaw Great Wood as estimated by Eco currently stands at over £220 million. Northaw Great Wood has the higher value of around £133 million, as a result of the size of this woodland area.

CAVAT - The amenity value of trees

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. The Council of Tree and Landscape Appraisers (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.

Particular differences to the CTLA valuation include the Community Tree Index (CTI) value, which adjusts the CAVAT assessment to take account of the greater benefits of trees in areas of higher population density, using official population figures. CAVAT allows the value of Welwyn Hatfield's street trees to include a social dimension by valuing the visual accessibility and prominence within the overall urban forest.

For the street trees of the urban forest of Welwyn Hatfield, the estimated total public amenity asset value is nearly £290 million.

For the woodland trees of Welwyn Hatfield, the estimated total public amenity asset value is over £3 billion.

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.

This study also included assumptions of Safe Useful Life Expectancy (SULE) based on the condition, as this was not included in the Welwyn Hatfield tree inventory information.

The English Oak (*Quercus robur*) amongst Welwyn Hatfield's street trees holds the highest CAVAT value (Table 5, below), although the Cherry (*Prunus*) is the most numerous tree, representing 11.2% of the total street tree population.

Species	CAVAT Value	Percent of Total Population	Replacement Cost
Quercus robur	£32,048,030.05	4.4%	£3,268,367.00
Prunus	£25,983,366.79	11.2%	£2,220,289.58
Betula pendula	£14,740,532.25	6.7%	£1,396,358.38
Malus	£13,542,014.26	6.0%	£1,321,794.74
Acer platanoides	£12,665,043.18	4.9%	£1,236,960.46
Fraxinus excelsior	£10,804,592.20	3.0%	£1,096,190.33
Tilia	£10,599,099.95	3.3%	£1,051,557.16
Carpinus betulus	£10,375,420.22	3.6%	£1,019,341.66
Populus nigra v. italica	£10,329,946.86	3.2%	£1,058,522.52
Crataegus	£9,776,820.69	3.6%	£865,372.34
All Other Species	£138,889,966.63	50.1%	£12,898,197.77
Total	**£289,754,833.08**	**100%**	**£27,432,951.94**

Table 5: The ten street tree species with the highest CAVAT valuation

Using this study

The results and data from previous i-Tree studies have been used in a variety of ways to improve management of trees and inform decision making. With better information we can make better decisions about how trees are managed to provide long-term benefits to communities This is one of the key outcomes of undertaking a project such as this.

For example:

- Data can be used to inform species selection for increased tree diversity thereby lessening the impacts from potential threats like *Hymenoscyphus fraxineus* (formerly *Chalara fraxinea*), more commonly known as Ash Dieback.

- Data can be used to produce educational information about Welwyn Hatfield's trees (e.g. informational tree tags).

- 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, in order to align to the objectives and priorities of Welwyn Hatfield's tree management plan.

- Inform species selection. Size does matter! Identify trees that can grow on to full maturity and reach their optimal canopy size (given any site specific restrictions) and contribute the most benefits to the surrounding urban communities. Review together with an ancient tree management plan to include non-natives and heritage trees to broaden the potential for Welwyn Hatfield's inventory trees and woodlands to build resilience to future change.

Conclusions and Recommendations

The tree population within Welwyn Hatfield's street tree inventory has a very good species and age diversity. It is acknowledged that there are a number of constraints on urban planting, which can hinder planting of larger-growing species. Additional larger-growing species provide some resilience from possible future influences such as climate change and pest and disease outbreaks. The role of Welwyn Hatfield's trees in complementing people's health is clear, through air pollution removal especially. Welwyn Hatfield's street trees provide a valuable benefit of over £104,000 in ecosystem services each year. The woodland belts alone sequestering an estimated 2,147 tonnes of carbon every year with a value of over £527,000.

In terms of structural diversity, the Oak (*Quercus robur*) has the largest proportion of street trees in the larger size classes within the top ten populated species. The majority of other species of high population are generally smaller statured species. Larger-growing trees are important because they provide greater canopy cover and therefore ecosystem service provision. They also tend to have higher amenity value than their smaller counterparts.

Welwyn Hatfield has a rich species diversity, with 237 species within the street tree inventory. However, there is a slight reliance on *Prunus* (due to its high population) and *Quercus robur* to provide ecosystem services, including 25.4% of all carbon stored, 20% of annual carbon sequestration, and 17.2% of annual avoided runoff. Like many urban areas, Welwyn Hatfield would benefit from having a greater proportion of larger trees, of a more diverse range of species, in order to build resilience into its tree population and reduce reliance on a small number of species.

The values presented in this study represent only a portion of the total value of the trees within Welwyn Hatfield because only a proportion of the total benefits have been evaluated. Trees confer many other benefits, such as contributions to our health and well-being, reducing urban temperatures, providing amenity value and habitats for wildlife. In addition, the woodland data assessed within this report only includes the two largest woodlands - Northaw Great Wood and Sherrardspark Wood. There are more areas of woodland and tree belts within Welwyn Hatfield, however it means that areas cleared for glades and ride management are accounted for. Therefore, the values presented in this report should be seen as conservative estimates.

The extent of these benefits needs to be recognised, and strategies and policies that will serve to conserve this important resource (through education for example) would be one way to address this. Targets to increase canopy cover, protect large and veteran trees, plant large trees where possible, diversify the urban forest and plant climate-adaptable species should also be investigated through the production of an ‘Urban Forest Masterplan’.

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. New tree planting can contribute to the growth of canopy cover. However, 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 Welwyn Hatfield’s tree inventory in a variety of ways and there are great uncertainties about how this may manifest. Some species may be less able to survive under new climatic conditions. New conditions may also allow different pests and diseases to become prevalent. Further studies into this area would be useful in informing any long-term tree strategies or urban forest masterplans, such as species choice for example.

The challenge now is to ensure that policy makers and practitioners take full account of Welwyn Hatfield's 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 the Welwyn Hatfield inventory 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 only as they are largely based on US values (see footnotes).

Street Tree Carbon storage is equivalent to:

- Amount of carbon emitted in Welwyn Hatfield Inventory in 6 days
- Annual carbon (C) emissions from 7,140 family cars
- Annual C emissions from 2,930 single-family houses

Woodland Carbon storage is equivalent to:

- Amount of carbon emitted in Welwyn Hatfield Woodlands in 47 days
- Annual carbon (C) emissions from 53,500 automobiles
- Annual C emissions from 21,900 single-family houses

Street Tree Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 112 family cars
- Annual nitrogen dioxide emissions from 51 single-family houses

Woodland Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 869 family cars
- Annual nitrogen dioxide emissions from 391 single-family houses

Street Tree Sulphur dioxide removal is equivalent to:

- Annual sulphur dioxide emissions from 1,040 family cars
- Annual sulphur dioxide emissions from 3 single-family houses

Woodland Sulphur dioxide removal is equivalent to:

- Annual sulphur dioxide emissions from 8,100 family cars
- Annual sulphur dioxide emissions from 21 single-family houses

Street Tree Carbon sequestration is equivalent to:

- Annual carbon (C) emissions from 200 family cars
- Annual C emissions from 100 single-family houses

Woodland Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Welwyn Hatfield Woodlands in 1.5 days
- Annual C emissions from 1,700 automobiles
- Annual C emissions from 700 single-family houses

Street Tree Oxygen Production is equivalent to:

- Annual Oxygen intake from 2,198 people

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO_2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (Energy Information Administration 2013; Energy Information Administration 2014):

- CO_2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM emission per kWh from Layton 2004.

- CO_2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO_2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Oxygen production figures are based on the total oxygen produced by the trees within the inventory divided by the average intake of oxygen for each person per year - https://ntrs.nasa.gov/search.jsp?R=20060005209

Appendix II. Street Tree Species Dominance Ranking List

Species	Percent Population	Percent Leaf Area	Dominance Value
Prunus	11.20	9.50	20.70
Acer platanoides	4.90	7.40	12.30
Quercus robur	4.40	7.70	12.00
Betula pendula	6.70	4.60	11.30
Malus	6.00	3.80	9.80
Tilia	3.30	4.50	7.80
Fraxinus excelsior	3.00	3.90	7.00
Carpinus betulus	3.60	3.30	7.00
Acer pseudoplatanus	2.30	3.60	5.90
Populus nigra v. italica	3.20	2.70	5.90
Prunus pissardii	3.00	2.80	5.80
Sorbus aucuparia	3.10	2.30	5.40
Platanus x acerifolia	1.40	3.70	5.10
Crataegus	3.60	1.40	4.90
Ulmus	2.00	2.50	4.50
Aesculus hippocastanum	1.60	2.70	4.40
Acer campestre	2.00	2.00	4.00
Fagus sylvatica	1.20	2.60	3.80
Tilia x vulgaris	1.10	1.80	2.90
Robinia pseudoacacia	1.30	1.60	2.90
Sorbus aria	1.70	1.20	2.90
Carpinus betulus 'Fastigiata'	1.20	1.20	2.40
Crataegus monogyna	1.80	0.60	2.40
Acer saccharinum	0.80	1.30	2.20
Populus	1.00	1.20	2.20
Sorbus intermedia	1.20	1.00	2.20
Fraxinus	1.00	1.00	2.10
Prunus avium	1.20	0.70	1.90

Species	Percent Population	Percent Leaf Area	Dominance Value
Betula	0.80	0.70	1.50
Acer	0.70	0.70	1.50
Larix	0.60	0.80	1.40
Salix	0.60	0.70	1.40
Sorbus	0.80	0.50	1.40
Castanea sativa	0.40	0.90	1.30
Quercus rubra	0.50	0.80	1.30
Quercus	0.50	0.80	1.20
Cupressus	0.70	0.20	1.00
Alnus glutinosa	0.50	0.40	0.90
Pinus sylvestris	0.50	0.40	0.80
Laburnum	0.30	0.40	0.70
Aesculus x carnea	0.30	0.40	0.60
Salix x chrysocoma	0.20	0.40	0.60
Taxus baccata 'fastigiata'	0.20	0.40	0.60
Aesculus	0.20	0.40	0.60
Prunus dulcis	0.30	0.30	0.60
Quercus petraea	0.20	0.30	0.60
Prunus padus	0.30	0.20	0.60
Populus nigra	0.20	0.40	0.50
Taxus	0.20	0.30	0.50
Acer platanoides 'Crimson King'	0.20	0.30	0.50
Tilia cordata	0.30	0.20	0.50
Pinus maritima	0.20	0.20	0.50
Malus domestica	0.40	0.10	0.50
Cupressocyparis leylandii	0.20	0.20	0.40
Populus alba	0.20	0.20	0.40
Fraxinus angustifolia 'Raywood'	0.20	0.20	0.40
Fraxinus ornus	0.20	0.20	0.40
Ilex	0.30	0.10	0.40
Pinus	0.20	0.10	0.40

Species	Percent Population	Percent Leaf Area	Dominance Value
Quercus cerris	0.10	0.20	0.30
Juglans regia	0.10	0.20	0.30
Salix alba	0.10	0.20	0.30
Ailanthus altissima	0.10	0.20	0.30
Prunus sargentii	0.30	0.10	0.30
Pinus nigra	0.20	0.10	0.30
Betula utilis ssp. jacquemontii	0.20	0.10	0.30
Crataegus x lavallei	0.20	0.10	0.30
Chamaecyparis	0.20	0.10	0.30
Prunus cerasifera 'Nigra'	0.20	0.10	0.30
Liquidambar styraciflua	0.30	<0.10	0.30
Pyrus calleryana 'Chanticleer'	0.30	<0.10	0.30
Crataegus prunifolia	0.30	<0.10	0.30
Crataegus laevigata	0.20	<0.10	0.30
Magnolia	0.20	0.10	0.20
Cedrus libani	0.10	0.10	0.20
Cotoneaster	0.10	0.10	0.20
Ulmus 'Sapporo Autunm Gold'	0.10	0.10	0.20
Salix caprea	0.10	0.10	0.20
Alnus	0.10	0.10	0.20
Prunus cerasifera	0.10	0.10	0.20
Tilia x europaea	0.10	0.10	0.20
Thuja plicata	0.10	0.10	0.20
Acer cappadocicum	0.10	0.10	0.20
Fagus sylvatica 'Purpurea'	0.10	0.10	0.20
Prunus serrulata 'Amanogawa'	0.10	0.10	0.20
Sorbus hupehensis	0.10	0.10	0.20
Robinia pseudoacacia 'Frisia'	0.10	0.10	0.20
Prunus domestica	0.20	<0.10	0.20

Species	Percent Population	Percent Leaf Area	Dominance Value
Prunus serrula	0.20	<0.10	0.20
Prunus x hiliieri	0.20	<0.10	0.20
Amelanchier lamarckii	0.10	<0.10	0.20
Abies alba	0.10	0.10	0.10
Tilia euchlora	0.10	0.10	0.10
Tilia tomentosa	0.10	0.10	0.10
Populus x canadensis	0.10	0.10	0.10
Corylus avellana	0.10	0.10	0.10
Juglans ailantifolia	<0.10	0.10	0.10
Quercus coccinea	<0.10	0.10	0.10
Populus canescens	<0.10	0.10	0.10
Corylus colurna	0.10	<0.10	0.10
Pyrus	0.10	<0.10	0.10
Prunus Kanzan	0.10	<0.10	0.10
Parrotia persica	0.10	<0.10	0.10
Amelanchier arborea	0.10	<0.10	0.10
Prunus subhirtella v. autumnalis	0.10	<0.10	0.10
Crataegus pedicellata	0.10	<0.10	0.10
Prunus serrulata 'Accolade'	0.10	<0.10	0.10
Prunus yedoensis	0.10	<0.10	0.10
Malus tschonoskii	0.10	<0.10	0.10
Sorbus commixta	0.10	<0.10	0.10
Catalpa bignonioides	0.10	<0.10	0.10
Acer x freemanii	0.10	<0.10	0.10
Sambucus nigra	0.10	<0.10	0.10
Mespilus germanica	0.10	<0.10	0.10
Prunus x schmittii	0.10	<0.10	0.10
Gleditsia triacanthos v. inermis 'Sunburst'	0.10	<0.10	0.10
Amelanchier x grandiflora 'Autumn'	0.10	<0.10	0.10
Koelreuteria paniculata	0.10	<0.10	0.10

Species	Percent Population	Percent Leaf Area	Dominance Value
Hippophae rhamnoides	0.10	<0.10	0.10
Pyrus communis	0.10	<0.10	0.10
Betula utilis	0.10	<0.10	0.10
Malus baccata	0.10	<0.10	0.10
Paulownia tomentosa	0.10	<0.10	0.10
Acer campestre 'Queen Elizabeth'	0.10	<0.10	0.10
Prunus virginiana 'Canada Red'	0.10	<0.10	0.10
Juglans nigra	0.10	<0.10	0.10
Magnolia kobus	0.10	<0.10	0.10
Fraxinus excelsior 'Pendula'	<0.10	<0.10	0.10
Alnus incana	<0.10	<0.10	0.10
Picea abies	<0.10	<0.10	0.10
Prunus lusitanica	<0.10	<0.10	0.10
Ulmus procera	<0.10	<0.10	0.10
Fraxinus pennsylvanica	<0.10	<0.10	0.10
Betula papyrifera	<0.10	<0.10	0.10
Cedrus atlantica v. glauca	<0.10	<0.10	0.10
Zelkova	<0.10	<0.10	0.10
Sorbus torminalis	<0.10	<0.10	0.10
Cupressocyparis	<0.10	<0.10	0.10
Aesculus indica	<0.10	<0.10	0.10
Alnus cordata	<0.10	<0.10	0.10
Quercus/live ilex	<0.10	<0.10	0.10
Ginkgo biloba	<0.10	<0.10	0.10
Prunus laurocerasus	<0.10	<0.10	0.10
Salix babylonica	<0.10	<0.10	0.10
Acer pseudoplatanus v. purpureum	<0.10	<0.10	0.10
Cedrus	<0.10	<0.10	0.10
Prunus spinosa	<0.10	<0.10	0.10
Platanus orientalis	<0.10	<0.10	<0.10

Species	Percent Population	Percent Leaf Area	Dominance Value
Betula nigra	<0.10	<0.10	<0.10
Ulmus 'New Horizon'	<0.10	<0.10	<0.10
Carpinus japonica	<0.10	<0.10	<0.10
Taxodium distichum	<0.10	<0.10	<0.10
Rhus	<0.10	<0.10	<0.10
Acer capillipes	<0.10	<0.10	<0.10
Crataegus chrysocarpa	<0.10	<0.10	<0.10
Morus nigra	<0.10	<0.10	<0.10
Populus tremula	<0.10	<0.10	<0.10
Pterocarya fraxinifolia	<0.10	<0.10	<0.10
Cercis siliquastrum	<0.10	<0.10	<0.10
Magnolia x soulangiana 'Galaxy'	<0.10	<0.10	<0.10
Eucalyptus	<0.10	<0.10	<0.10
Gleditsia triacanthos	<0.10	<0.10	<0.10
Liriodendron tulipifera 'Aureomarginatum'	<0.10	<0.10	<0.10
Pinus pinaster	<0.10	<0.10	<0.10
Liriodendron tulipifera	<0.10	<0.10	<0.10
Tilia platyphyllos	<0.10	<0.10	<0.10
Acer buergerianum	<0.10	<0.10	<0.10
Tilia mongolica	<0.10	<0.10	<0.10
Ulmus glabra	<0.10	<0.10	<0.10
Sorbus hybrida	<0.10	<0.10	<0.10
Araucaria araucana	<0.10	<0.10	<0.10
Prunus Shirotae	<0.10	<0.10	<0.10
Ulmus x rebona	<0.10	<0.10	<0.10
Malus John Downie	<0.10	<0.10	<0.10
Nothofagus obliqua	<0.10	<0.10	<0.10
Malus toringoides	<0.10	<0.10	<0.10
Betula ermanii	<0.10	<0.10	<0.10
Sorbus x thuringiaca	<0.10	<0.10	<0.10
Ostrya carpinifolia	<0.10	<0.10	<0.10

Species	Percent Population	Percent Leaf Area	Dominance Value
Laburnum x watereri	<0.10	<0.10	<0.10
Betula albosinensis	<0.10	<0.10	<0.10
Sequoiadendron giganteum	<0.10	<0.10	<0.10
Cercis canadensis	<0.10	<0.10	<0.10
Salix pentandra	<0.10	<0.10	<0.10
Acer griseum	<0.10	<0.10	<0.10
Acer rubrum 'Brandywine'	<0.10	<0.10	<0.10
Syringa	<0.10	<0.10	<0.10
Pyrus calleryana 'Red Spire'	<0.10	<0.10	<0.10
Malus floribunda	<0.10	<0.10	<0.10
Cornus kousa	<0.10	<0.10	<0.10
Prunus incisa	<0.10	<0.10	<0.10
Ulmus 'Lobel'	<0.10	<0.10	<0.10
Ligustrum lucidum	<0.10	<0.10	<0.10
Fraxinus velutina	<0.10	<0.10	<0.10
Pseudotsuga menziesii	<0.10	<0.10	<0.10
Quercus palustris	<0.10	<0.10	<0.10
Acer negundo	<0.10	<0.10	<0.10
Acer rubrum	<0.10	<0.10	<0.10
Fraxinus angustifolia	<0.10	<0.10	<0.10
Ligustrum	<0.10	<0.10	<0.10
Gleditsia	<0.10	<0.10	<0.10
Prunus serotina	<0.10	<0.10	<0.10
Platanus orientalis digitata	<0.10	<0.10	<0.10
Magnolia x soulangeana	<0.10	<0.10	<0.10
Ficus carica	<0.10	<0.10	<0.10
Acer ginnala	<0.10	<0.10	<0.10
Sorbus thibetica 'John Mitchell'	<0.10	<0.10	<0.10
Quercus frainetto	<0.10	<0.10	<0.10
Acer palmatum	<0.10	<0.10	<0.10
Prunus maackii	<0.10	<0.10	<0.10

Species	Percent Population	Percent Leaf Area	Dominance Value
Cydonia oblonga	<0.10	<0.10	<0.10
Sorbus sargentiana	<0.10	<0.10	<0.10
Juniperus	<0.10	<0.10	<0.10
Betula pubescens	<0.10	<0.10	<0.10
Abies	<0.10	<0.10	<0.10
Buxus sempervirens	<0.10	<0.10	<0.10
Pyrus salicifolia	<0.10	<0.10	<0.10
Crataegus x grignonensis	<0.10	<0.10	<0.10
Viburnum	<0.10	<0.10	<0.10
Quercus robur 'Fastigiata'	<0.10	<0.10	<0.10
Liriodendron tulipifera 'Fastigiatum'	<0.10	<0.10	<0.10
Acer cappadocicum ssp. Lobelii	<0.10	<0.10	<0.10
Acer rubrum 'October glory'	<0.10	<0.10	<0.10
Acer rubrum 'Red Sunset'	<0.10	<0.10	<0.10
Magnolia x loebneri	<0.10	<0.10	<0.10
Nothofagus antarctica	<0.10	<0.10	<0.10
Morus	<0.10	<0.10	<0.10
Nyssa sylvatica	<0.10	<0.10	<0.10
Davidia involucrata	<0.10	<0.10	<0.10
Platanus	<0.10	<0.10	<0.10
Prunus fruticosa	<0.10	<0.10	<0.10
Cercidiphyllum japonicum	<0.10	<0.10	<0.10
Quercus castaneifolia	<0.10	<0.10	<0.10
Salix alba 'Tristis'	<0.10	<0.10	<0.10
Wollemia nobilis	<0.10	<0.10	<0.10
Cupressus arizonica	<0.10	<0.10	<0.10
Metasequoia glyptostroboides	<0.10	<0.10	<0.10

Appendix III. Street Tree Values by Species

Species	Trees	Carbon Storage (Tonnes)	Gross Carbon Seq (Tonnes/ Yr)	Avoided Runoff (m^3/Yr)	Pollution Removal (Tonne/ Yr)	Replacement Cost (£)
Quercus robur	737	1436.50	18.83	516.25	0.27	£ 3268367.00
Prunus	1899	888.78	28.37	639.97	0.33	£ 2220289.58
Betula pendula	1129	491.92	17.01	308.44	0.16	£ 1396358.38
Malus	1021	374.47	12.36	256.54	0.13	£ 1321794.74
Acer platanoides	831	369.08	11.25	496.93	0.26	£ 1236960.46
Fraxinus excelsior	513	309.70	7.09	264.47	0.14	£ 1096190.33
Populus nigra v. italica	545	259.07	7.22	181.08	0.09	£ 1058522.52
Tilia	557	201.84	5.72	302.94	0.16	£ 1051557.16
Carpinus betulus	616	311.51	8.80	224.93	0.12	£ 1019341.66
Crataegus	602	276.00	8.67	92.17	0.05	£ 865372.34
Platanus x acerifolia	235	266.81	5.46	250.25	0.13	£ 797328.46
Acer pseudoplatanus	386	252.21	6.31	242.23	0.13	£ 781768.14
Prunus pissardii	503	259.98	8.40	189.69	0.10	£ 646891.16
Sorbus aucuparia	532	183.25	6.19	152.23	0.08	£ 623052.27
Fagus sylvatica	198	220.62	4.36	178.12	0.09	£ 556430.93
Robinia pseudoacacia	216	167.28	4.37	108.90	0.06	£ 540440.69
Aesculus hippocastanum	275	246.57	5.37	184.07	0.10	£ 498355.80
Populus	172	160.65	3.33	81.26	0.04	£ 483940.40
Acer saccharinum	141	111.41	2.26	90.61	0.05	£ 389904.89
Tilia x vulgaris	190	69.25	2.14	119.58	0.06	£ 382443.27
Carpinus betulus 'Fastigiata'	197	111.10	3.19	81.70	0.04	£ 374682.65
Castanea sativa	68	148.65	1.83	61.65	0.03	£ 367278.60
Quercus	83	138.68	2.26	50.70	0.03	£ 326997.72
Sorbus aria	287	94.13	3.35	83.74	0.04	£ 316220.32
Crataegus monogyna	299	102.40	3.44	42.70	0.02	£ 314563.52
Acer campestre	346	100.04	3.42	131.75	0.07	£ 305531.73
Quercus rubra	81	100.55	2.17	52.76	0.03	£ 280424.90
Salix	106	86.25	2.05	49.24	0.03	£ 270441.52

Species	Trees	Carbon Storage (Tonnes)	Gross Carbon Seq (Tonnes/ Yr)	Avoided Runoff (m^3/Yr)	Pollution Removal (Tonne/ Yr)	Replacement Cost (£)	
Fraxinus	177	71.53	2.01	70.05	0.04	£	267063.29
Sorbus intermedia	201	77.19	2.63	65.26	0.03	£	260941.17
Prunus avium	203	81.14	2.38	49.69	0.03	£	228619.43
Salix x chrysocoma	41	67.64	1.20	25.71	0.01	£	197648.48
Populus nigra	28	55.11	0.89	23.92	0.01	£	172531.73
Ulmus	338	90.70	3.41	170.48	0.09	£	162571.06
Quercus petraea	36	61.48	1.10	23.27	0.01	£	150376.12
Betula	137	50.39	1.85	46.94	0.02	£	141287.93
Sorbus	143	37.40	1.43	36.29	0.02	£	126127.53
Acer	122	41.18	1.30	50.48	0.03	£	124140.95
Cupressus	125	27.71	0.71	15.82	0.01	£	118709.74
Taxus	31	22.28	0.36	20.20	0.01	£	116177.79
Pinus sylvestris	79	19.19	0.55	24.04	0.01	£	114056.50
Cedrus libani	15	20.86	0.26	8.70	<0.01	£	112131.39
Alnus glutinosa	88	30.22	1.03	28.54	0.01	£	98079.25
Taxus baccata 'fastigiata'	36	14.30	0.35	24.86	0.01	£	89539.59
Populus alba	33	20.44	0.57	14.23	0.01	£	85350.87
Pinus maritima	38	13.97	0.35	15.73	0.01	£	84017.53
Pinus nigra	33	9.60	0.24	9.80	0.01	£	78651.92
Quercus cerris	24	29.84	0.64	13.58	0.01	£	77630.62
Cupressocyparis leylandii	41	18.69	0.34	12.80	0.01	£	77221.41
Aesculus x carnea	44	20.61	0.64	25.57	0.01	£	67577.26
Aesculus	33	22.48	0.65	24.81	0.01	£	64125.58
Larix	99	26.54	0.75	51.89	0.03	£	63121.54
Laburnum	59	27.56	0.87	24.40	0.01	£	62766.47
Prunus padus	59	24.15	0.69	15.69	0.01	£	62338.96
Salix caprea	15	21.13	0.34	7.91	<0.01	£	59029.09
Salix alba	22	17.21	0.47	11.35	0.01	£	58571.51
Prunus dulcis	57	27.36	0.87	19.66	0.01	£	55445.11
Tilia cordata	43	10.29	0.33	16.29	0.01	£	54862.59

Species	Trees	Carbon Storage (Tonnes)	Gross Carbon Seq (Tonnes/ Yr)	Avoided Runoff (m^3/Yr)	Pollution Removal (Tonne/ Yr)	Replacement Cost (£)	
Pinus	37	9.23	0.22	9.09	<0.01	£	52412.76
Ilex	46	15.22	0.54	8.42	<0.01	£	50578.47
Acer platanoides 'Crimson King'	36	14.13	0.46	17.54	0.01	£	44927.72
Ailanthus altissima	22	15.33	0.40	10.57	0.01	£	44555.65
Fraxinus angustifolia 'Raywood'	40	9.15	0.29	10.11	0.01	£	35202.18
Fagus sylvatica 'Purpurea'	10	15.77	0.22	6.82	<0.01	£	33954.69
Populus x canadensis	10	7.85	0.19	4.86	<0.01	£	30407.18
Betula utilis ssp. jacquemontii	32	9.72	0.36	9.14	<0.01	£	27973.38
Fraxinus ornus	36	7.26	0.27	10.17	0.01	£	26315.90
Populus canescens	6	6.58	0.15	3.91	<0.01	£	25620.98
Juglans regia	22	7.34	0.24	12.24	0.01	£	25377.78
Tilia tomentosa	9	4.69	0.10	5.31	<0.01	£	23970.18
Thuja plicata	17	1.97	0.05	4.89	<0.01	£	23513.46
Alnus	18	7.05	0.24	6.54	<0.01	£	23129.52
Chamaecyparis	29	5.11	0.15	5.95	<0.01	£	22847.54
Crataegus x lavallei	33	7.51	0.28	4.39	<0.01	£	22771.63
Malus domestica	75	5.22	0.22	5.92	<0.01	£	22416.65
Magnolia	28	6.10	0.15	3.82	<0.01	£	20632.09
Hippophae rhamnoides	10	6.30	0.18	1.82	<0.01	£	20194.44
Tilia x europaea	15	3.13	0.11	5.75	<0.01	£	17345.16
Sorbus commixta	10	4.94	0.14	3.36	<0.01	£	17156.19
Quercus coccinea	8	5.99	0.16	3.49	<0.01	£	17111.67
Cotoneaster	21	7.48	0.26	6.25	<0.01	£	16935.59
Robinia pseudoacacia 'Frisia'	14	4.85	0.16	4.57	<0.01	£	15960.28
Tilia euchlora	11	2.84	0.09	5.03	<0.01	£	15839.99
Malus tschonoskii	11	4.36	0.15	3.07	<0.01	£	15617.76
Catalpa bignonioides	12	5.28	0.13	2.42	<0.01	£	15595.41
Pyrus	14	4.40	0.15	3.09	<0.01	£	15347.11

Species	Trees	Carbon Storage (Tonnes)	Gross Carbon Seq (Tonnes/Yr)	Avoided Runoff (m³/Yr)	Pollution Removal (Tonne/Yr)	Replacement Cost (£)	
Corylus avellana	9	4.51	0.14	3.60	<0.01	£	14671.63
Prunus cerasifera	17	7.34	0.25	5.70	<0.01	£	14211.27
Ulmus 'Sapporo Autunm Gold'	11	9.29	0.23	9.73	0.01	£	13923.59
Abies alba	10	3.22	0.08	5.88	<0.01	£	13655.05
Prunus spinosa	4	4.82	0.10	1.81	<0.01	£	13123.78
Sambucus nigra	14	3.61	0.12	1.03	<0.01	£	13091.33
Cedrus	5	1.84	0.04	1.55	<0.01	£	13044.82
Prunus serrulata 'Amanogawa'	18	4.59	0.16	3.59	<0.01	£	12139.21
Sequoiadendron giganteum	1	2.89	0.03	1.03	<0.01	£	11900.41
Prunus lusitanica	6	4.00	0.12	2.62	<0.01	£	11527.18
Cedrus atlantica v. glauca	7	1.62	0.05	1.85	<0.01	£	11239.21
Acer cappadocicum	15	3.50	0.13	5.18	<0.01	£	10823.56
Prunus cerasifera 'Nigra'	31	4.38	0.21	5.04	<0.01	£	10736.94
Alnus incana	7	3.07	0.10	2.86	<0.01	£	10471.55
Fraxinus excelsior 'Pendula'	7	2.46	0.08	2.98	<0.01	£	9368.77
Prunus Kanzan	14	3.38	0.12	2.82	<0.01	£	8942.43
Sorbus torminalis	8	2.69	0.06	1.08	<0.01	£	8684.55
Sorbus hupehensis	17	2.73	0.13	3.45	<0.01	£	8551.25
Amelanchier lamarckii	24	2.53	0.13	2.52	<0.01	£	8392.35
Cupressocyparis	6	1.65	0.05	1.87	<0.01	£	8105.26
Crataegus pedicellata	16	2.91	0.13	1.64	<0.01	£	7822.75
Alnus cordata	5	2.18	0.07	2.02	<0.01	£	7600.08
Fraxinus angustifolia	1	2.06	0.03	0.66	<0.01	£	7468.26
Salix babylonica	5	2.16	0.07	1.73	<0.01	£	7452.66
Betula papyrifera	6	2.71	0.11	2.39	<0.01	£	7413.19
Populus tremula	4	1.71	0.06	1.33	<0.01	£	7382.00
Juglans ailantifolia	7	2.27	0.08	4.28	<0.01	£	7350.26
Corylus colurna	18	2.08	0.08	2.52	<0.01	£	7234.36
Pyrus calleryana 'Chanticleer'	50	2.41	0.19	2.97	<0.01	£	7039.74

Species	Trees	Carbon Storage (Tonnes)	Gross Carbon Seq (Tonnes/ Yr)	Avoided Runoff (m³/Yr)	Pollution Removal (Tonne/ Yr)	Replacement Cost (£)	
Rhus	7	2.27	0.08	0.33	<0.01	£	6913.07
Crataegus prunifolia	43	2.33	0.16	2.36	<0.01	£	6738.33
Acer pseudoplatanus v. purpureum	4	1.99	0.06	2.08	<0.01	£	6673.29
Prunus sargentii	43	2.37	0.16	4.03	<0.01	£	6519.76
Koelreuteria paniculata	9	2.16	0.08	2.29	<0.01	£	6270.88
Platanus orientalis	3	1.63	0.05	2.12	<0.01	£	5655.52
Pinus pinaster	3	0.92	0.02	1.04	<0.01	£	5655.52
Sorbus hybrida	2	1.62	0.04	1.04	<0.01	£	5573.96
Prunus domestica	31	2.49	0.13	3.14	<0.01	£	5502.66
Crataegus laevigata	38	1.57	0.11	1.78	<0.01	£	5471.20
Zelkova	6	1.78	0.07	2.05	<0.01	£	5469.87
Aesculus indica	4	2.00	0.06	2.60	<0.01	£	5408.19
Eucalyptus	2	2.70	0.05	1.81	<0.01	£	5113.57
Quercus/live ilex	7	1.56	0.06	1.18	<0.01	£	4928.58
Pterocarya fraxinifolia	3	1.54	0.05	1.70	<0.01	£	4764.12
Liquidambar styraciflua	51	1.32	0.09	3.18	<0.01	£	4504.48
Tilia platyphyllos	2	0.79	0.02	1.31	<0.01	£	4268.21
Fraxinus pennsylvanica	7	0.96	0.04	2.03	<0.01	£	3945.91
Prunus laurocerasus	6	1.37	0.06	1.36	<0.01	£	3809.04
Prunus x schmittii	11	1.53	0.08	2.00	<0.01	£	3321.09
Prunus serrula	27	1.69	0.12	3.06	<0.01	£	3148.52
Betula utilis	10	1.06	0.06	1.45	<0.01	£	3147.45
Syringa	3	0.86	0.03	0.13	<0.01	£	3058.17
Araucaria araucana	2	0.51	0.01	1.04	<0.01	£	2997.75
Ginkgo biloba	8	0.86	0.03	0.73	<0.01	£	2980.74
Betula nigra	5	1.13	0.05	1.30	<0.01	£	2923.08
Acer negundo	1	0.82	0.02	0.70	<0.01	£	2786.98
Cercis siliquastrum	5	0.85	0.03	0.80	<0.01	£	2769.05
Picea abies	8	1.06	0.04	2.09	<0.01	£	2724.02
Magnolia x soulangeana	1	0.79	0.02	0.55	<0.01	£	2626.81

Species	Trees	Carbon Storage (Tonnes)	Gross Carbon Seq (Tonnes/ Yr)	Avoided Runoff (m³/Yr)	Pollution Removal (Tonne/ Yr)	Replacement Cost (£)	
Ficus carica	1	0.80	0.02	0.52	<0.01	£	2481.29
Ulmus procera	6	1.59	0.05	2.50	<0.01	£	2427.58
Prunus serotina	1	0.99	0.03	0.60	<0.01	£	2395.41
Taxodium distichum	5	0.49	0.02	1.18	<0.01	£	2262.18
Pseudotsuga menziesii	1	0.38	0.01	0.79	<0.01	£	2218.43
Quercus frainetto	1	0.74	0.02	0.48	<0.01	£	2197.24
Ligustrum	1	0.83	0.02	0.66	<0.01	£	1905.96
Prunus x hiliieri	26	0.28	0.04	1.19	<0.01	£	1899.87
Amelanchier arborea	19	0.31	0.03	0.72	<0.01	£	1898.86
Gleditsia triacanthos v. inermis 'Sunburst'	12	0.80	0.06	1.29	<0.01	£	1798.08
Nothofagus obliqua	2	0.73	0.03	0.89	<0.01	£	1736.26
Salix pentandra	2	0.47	0.02	0.54	<0.01	£	1601.01
Acer x freemanii	13	0.58	0.04	1.78	<0.01	£	1594.45
Prunus serrulata 'Accolade'	17	0.48	0.05	1.20	<0.01	£	1551.96
Prunus subhirtella v. autumnalis	18	0.35	0.04	1.03	<0.01	£	1517.52
Parrotia persica	19	0.25	0.03	0.82	<0.01	£	1495.18
Prunus yedoensis	17	0.38	0.04	1.06	<0.01	£	1452.26
Amelanchier x grandiflora 'Autumn'	14	0.04	0.01	0.31	<0.01	£	1155.94
Malus baccata	12	0.12	0.02	0.59	<0.01	£	1111.78
Pyrus communis	13	0.12	0.02	0.29	<0.01	£	1093.03
Malus toringoides	3	0.31	0.02	0.43	<0.01	£	1071.70
Sorbus x thuringiaca	3	0.25	0.01	0.38	<0.01	£	963.63
Paulownia tomentosa	12	0.04	0.01	0.39	<0.01	£	888.09
Acer campestre 'Queen Elizabeth'	10	0.05	0.01	0.46	<0.01	£	853.12
Mespilus germanica	15	0.05	0.01	0.44	<0.01	£	813.66
Acer capillipes	5	0.36	0.03	1.09	<0.01	£	764.72
Juglans nigra	9	0.03	0.01	0.40	<0.01	£	734.06
Magnolia kobus	9	0.03	0.01	0.40	<0.01	£	734.06

Species	Trees	Carbon Storage (Tonnes)	Gross Carbon Seq (Tonnes/ Yr)	Avoided Runoff (m^3/Yr)	Pollution Removal (Tonne/ Yr)	Replacement Cost (£)
Prunus virginiana 'Canada Red'	10	0.03	0.01	0.33	<0.01	£ 692.37
Crataegus chrysocarpa	7	0.20	0.02	0.29	<0.01	£ 677.69
Gleditsia triacanthos	5	0.28	0.02	0.45	<0.01	£ 649.80
Juniperus	1	0.15	0.01	0.41	<0.01	£ 594.89
Carpinus japonica	7	0.02	0.01	0.45	<0.01	£ 575.62
Morus nigra	7	0.02	0.01	0.27	<0.01	£ 511.85
Liriodendron tulipifera	3	0.22	0.01	1.00	<0.01	£ 492.17
Ulmus glabra	3	0.27	0.01	0.76	<0.01	£ 486.36
Magnolia x soulangiana 'Galaxy'	6	0.02	0.01	0.27	<0.01	£ 484.69
Betula ermanii	3	0.20	0.02	0.41	<0.01	£ 460.83
Acer buergerianum	4	0.12	0.01	0.44	<0.01	£ 449.91
Tilia mongolica	4	0.09	0.01	0.37	<0.01	£ 434.32
Quercus palustris	2	0.19	0.01	0.35	<0.01	£ 379.27
Liriodendron tulipifera 'Aureomarginatum'	5	0.01	<0.01	0.25	<0.01	£ 363.84
Betula albosinensis	3	0.11	0.01	0.26	<0.01	£ 352.76
Pyrus calleryana 'Red Spire'	3	0.09	0.01	0.13	<0.01	£ 352.76
Gleditsia	2	0.17	0.01	0.25	<0.01	£ 334.52
Ostrya carpinifolia	3	0.08	0.01	0.30	<0.01	£ 324.89
Ulmus 'New Horizon'	5	0.37	0.03	1.26	<0.01	£ 323.68
Malus John Downie	4	0.01	<0.01	0.14	<0.01	£ 307.50
Acer rubrum	2	0.10	0.01	0.30	<0.01	£ 271.20
Prunus Shirotae	4	0.03	0.01	0.15	<0.01	£ 257.05
Acer griseum	3	0.01	<0.01	0.14	<0.01	£ 254.06
Acer rubrum 'Brandywine'	3	0.01	<0.01	0.14	<0.01	£ 244.69
Malus floribunda	3	0.01	<0.01	0.12	<0.01	£ 244.69
Fraxinus velutina	3	0.01	<0.01	0.08	<0.01	£ 244.69
Laburnum x watereri	3	0.10	0.01	0.27	<0.01	£ 232.82
Prunus incisa	3	0.01	<0.01	0.10	<0.01	£ 219.65
Cercis canadensis	3	0.04	0.01	0.19	<0.01	£ 215.82

Species	Trees	Carbon Storage (Tonnes)	Gross Carbon Seq (Tonnes/ Yr)	Avoided Runoff (m³/Yr)	Pollution Removal (Tonne/ Yr)	Replacement Cost (£)	
Betula pubescens	1	0.10	0.01	0.20	<0.01	£	200.53
Viburnum	1	0.08	0.01	0.06	<0.01	£	200.53
Pyrus salicifolia	1	0.08	0.01	0.09	<0.01	£	189.63
Buxus sempervirens	1	0.09	0.01	0.13	<0.01	£	176.87
Acer ginnala	2	0.01	<0.01	0.12	<0.01	£	172.50
Cornus kousa	3	0.01	<0.01	0.11	<0.01	£	167.68
Crataegus x grignonensis	1	0.09	0.01	0.08	<0.01	£	167.26
Platanus orientalis digitata	2	0.02	<0.01	0.16	<0.01	£	163.12
Sorbus thibetica 'John Mitchell'	2	0.02	<0.01	0.09	<0.01	£	163.12
Acer palmatum	2	0.01	<0.01	0.07	<0.01	£	163.12
Sorbus sargentiana	2	0.01	<0.01	0.06	<0.01	£	163.12
Ligustrum lucidum	3	0.01	<0.01	0.09	<0.01	£	161.49
Prunus maackii	2	0.01	<0.01	0.07	<0.01	£	142.45
Ulmus 'Lobel'	2	0.15	0.01	0.49	<0.01	£	125.16
Abies	1	0.07	<0.01	0.16	<0.01	£	117.96
Ulmus x rebona	4	0.01	<0.01	0.15	<0.01	£	107.66
Cydonia oblonga	2	0.01	<0.01	0.06	<0.01	£	107.66
Salix alba 'Tristis'	1	<0.01	<0.01	0.02	<0.01	£	86.25
Quercus robur 'Fastigiata'	1	0.02	<0.01	0.06	<0.01	£	81.56
Acer cappadocicum ssp. Lobelii	1	<0.01	<0.01	0.05	<0.01	£	81.56
Acer rubrum 'October glory'	1	<0.01	<0.01	0.05	<0.01	£	81.56
Acer rubrum 'Red Sunset'	1	<0.01	<0.01	0.05	<0.01	£	81.56
Magnolia x loebneri	1	<0.01	<0.01	0.04	<0.01	£	81.56
Quercus castaneifolia	1	<0.01	<0.01	0.03	<0.01	£	81.56
Davidia involucrata	1	<0.01	<0.01	0.04	<0.01	£	76.07
Nyssa sylvatica	1	<0.01	<0.01	0.04	<0.01	£	76.07
Morus	1	<0.01	<0.01	0.04	<0.01	£	71.94
Cercidiphyllum japonicum	1	<0.01	<0.01	0.03	<0.01	£	71.94
Prunus fruticosa	1	<0.01	<0.01	0.03	<0.01	£	69.24

Species	Trees	Carbon Storage (Tonnes)	Gross Carbon Seq (Tonnes/ Yr)	Avoided Runoff (m³/Yr)	Pollution Removal (Tonne/ Yr)	Replacement Cost (£)
Liriodendron tulipifera 'Fastigiatum'	1	<0.01	<0.01	0.05	<0.01	£ 67.81
Wollemia nobilis	1	<0.01	<0.01	0.02	<0.01	£ 63.67
Metasequoia glyptostroboides	1	<0.01	<0.01	0.02	<0.01	£ 60.01
Platanus	1	<0.01	<0.01	0.04	<0.01	£ 58.12
Nothofagus antarctica	1	<0.01	<0.01	0.04	<0.01	£ 53.83
Cupressus arizonica	1	<0.01	<0.01	0.02	<0.01	£ 53.83
Total	16,922	9,156.49	236.57	6,733.53	3.52	£27,432,951.94

Appendix IV. Notes on Methodology

Data Formatting - Street Trees

Tables 5 to 9, below show the list of edits which were made for this project, to enable the tree inventory to be processed.

In total 29,746 records were provided.

Reason for Addition	Details	Number of records added
Count column lists duplicate trees	These are trees which have duplicate details in each column.	65
	NUMBER OF RECORDS IMPORTED	**16922**

Table 6: Group Records added to Inventory

Reason for Removal	Details	Number of records removed
No Species	There is no data in this field (a minimum requirement for iTree)	71
No DBH	There is no data in this field (a minimum requirement for iTree)	818
Not Required	Record removed at the request of Welwyn Hatfield Borough Council.	12,000
	NUMBER OF RECORDS REMOVED	**12,889**

Table 7: Inventory Records removed for use in i-Tree

Condition Text	iTree Equivalent
Good Condition	92%
Reasonable Condition	87%
Fair Condition	82%
Poor Condition	62%
Dead Condition	0
No Condition	87%

Table 8: Condition Equivalents for use in iTree

Trunk Band	Trunk Value	DBH Average
1	Up to 10cm	5
2	10cm to 30cm	20
3	30cm to 60cm	45
4	60cm to 100cm	80
5	Over 100cm	120
6	Multi-stemmed	50

Table 9: Individual Record dbh Estimates

- NO SPECIES

Mixed Species -

75 x Oak
75 x Hornbeam
36 x Birch

New Tree -

3 x Oak
3 x Hornbeam
2 x Birch

Unknown -

10 x Oak
9 x Hornbeam
9 x Birch

- NO DBH

8,189 records estimated based upon age class.

- CAVAT

- Safe Useful Life Expectancy (SULE) - Based upon crown condition

Crown Condtion	SULE Value	SULE Percentage
92%	80+	100%
87%	40 - 80	95%
82%	20 - 40	80%
62%	10 - 20	55%
0	0	0%

Table 10: SULE Assumptions for the CAVAT Calculation

Data Formatting - Woodlands

Some assumptions/averages were made for the woodland areas of Welwyn Hatfield, these can be found in table 11 below.

	Location	Assumption Applied
Species Mix	Sherrardspark Wood	50% English Oak (*Quercus robur*) 50% Hornbeam (*Carpinus Betulus*)
	Northaw Great Wood	40% English Oak (*Quercus robur*) 40% Hornbeam (*Carpinus Betulus*) 20% Birch (*Betula pendula*)
Diameter	Sherrardspark Wood & Northaw Great Wood	30-60cm so an average of 45cm was applied for all trees.
Woodland Density	Sherrardspark Wood & Northaw Great Wood	The woodland density has been set at 500 trees per hectare.

Table 11: Assumptions made for Woodland Trees.

i-Tree Methodology

i-Tree Eco is designed to use standardised field data 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.

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[16]. 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

[16] Nowak 1994

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[17].

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[18]. 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[19] [20] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere[21]. 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[22] [23].

For a full review of the model see UFORE (2010) and Nowak and Crane (2000).
For UK implementation see Rogers et al (2014).
Full citation details are located in the bibliography section

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17 Nowak, David J., Hoehn, R., and Crane, D. 2007.

18 Baldocchi 1987, 1988

19 Bidwell and Fraser 1972

20 Lovett 1994

21 Zinke 1967

22 Hollis, 2007

23 Rogers et al (2012)

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 data.

The CTI rating is determined from the approved list (LTOA 2012) and is calculated on a borough by borough basis. The CTI for Welwyn Hatfield is 1.00, thereby maintaining the basic CAVAT value.

Accessibility, i.e. the ability of the public to benefit from the amenity value of trees, 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. For this study, park trees and street trees only were included, with 100% accessibility therefore assumed.

Safe Useful Life Expectancy assessment was based upon the condition of the tree within the inventory.

For full details of the method refer to Doick, et al (2018)[24]

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[24] Doick, *et al* (2018)

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