# GREEN BENEFITS IN VICTORIA BUSINESS IMPROVEMENT DISTRICT

An analysis of the benefits of trees and other green assets in the Victoria Business Improvement District.

AN I-TREE ECO, CAVAT AND G.I. VALUATION STUDY

LONDON climate change PARTNERSHIP

Treeco₂nomics

MAYOR OF LONDON

Victoria
BUSINESS IMPROVEMENT DISTRICT

# FOREWORD →

Victoria is a major transport hub, tourist destination and centre for business and commerce. The Victoria Business Improvement District acts as a platform for business to take a lead in enhancing the overall urban environment of Victoria and to help shape the area for future development. In this context it has a remit to support the green agenda as part of an integrated approach for promoting economic growth. Research shows that improved physical environments are also beneficial to both social and economic conditions.

Like many urban areas Victoria suffers from the effects of a high density built environment with an overall lack of natural features and this contributes to overheating in the summer through the urban heat island effect as well as surface water flooding, when the drainage system cannot accommodate the volume of water running off of hard surfaces.

Environment Agency data indicates that extensive areas of Westminster are prone to surface water flooding and this includes many parts of Victoria. These instances are likely to become more frequent under predicted climate change patterns with average winter rainfall expected to increase by between 12-16% by 2050 and by 16-26% by 2080. This is significant in an area which already suffers an economic disadvantage when surface water flooding causes Victoria Station to close.

Trees intercept rainwater thus reducing the burden on the drainage system; they cool the air and provide invaluable shade on a sunny day, and, of immediate benefit to Victoria in the face of major redevelopment, they can contribute to cleaning the dust and pollution from the air we breathe. So clearly Victoria's street trees and those in public and private green space have a central role in mitigating these environmental challenges and so contribute to making Victoria a better place to do business.

The Victoria BID considers trees to be a core component of the local infrastructure and has therefore commissioned the research presented in this report to provide a clearer understanding of the financial benefits of trees in a specific location so that we can say with confidence that our trees are saving the business community thousands of pounds per annum.

It is clear then that Victoria's trees are an asset that need to be carefully managed. We will use the results from this research to inform the detailed delivery of our BID wide green infrastructure programme, seeking to use natural features such as trees to make Victoria an attractive place to work and visit, but also one that is resilient to current environmental challenges and the anticipated effects of future climate change.

**Tom Foulkes, Chairman**
**Victoria Business Improvement District**

## THE AUTHORS

Kenton Rogers
Anne Jaluzot
Christopher Neilan

These London planes line Birdcage Walk near the Palace. The tree in foreground is tree no. 260, it has a recorded leaf area of 712m² and stores around 10,682 kg of carbon. Collectively Victoria's London planes store 662 tonnes of carbon.

The London plane is one of the largest broadleaf species and does particularly well in the urban environment tolerating both pollution and heavy pruning.

## SUMMARY

Green infrastructure can deliver benefits to urban areas. Trees in particular can provide a wide range of benefits (or ecosystem services) such as storing carbon, reducing the urban heat island effect and improving air quality. Understanding the structure, function and value of Victoria Business Improvement District's green infrastructure can inform decisions that will improve human health and environmental quality.

This report presents a baseline quantitative assessment of the air pollution, amenity, carbon storage and sequestration benefits of trees as well as the storm water and surface temperature benefits of existing green infrastructure in the Victoria BID. This is accompanied with detailed information on the character of the Victoria BID's existing treescape.

This report also estimates the additional benefits that could be generated if the 5% canopy cover increase target set by the Mayor of London for Greater London, by 2025, and the potential green roofs and ground level green spaces investments identified by the BID are both realised in Victoria.

This assessment was conducted using the i-Tree Eco model (also known as UFORE[1]), as developed by the U.S. Forest Service, Northern Research Station, Capital Asset Valuation for Amenity Trees (CAVAT) and tools within the Green Infrastructure Valuation Toolkit. It considers the impact of public and private trees as well as other types of green infrastructure assets including green roofs and gardens.

**Number of trees:** Total number of tree species recorded with a diameter greater than 70mm at 1.3m above ground level

**US Externality Costs:** Based on the cost of abating the amount of pollution which is mitigated by the trees recorded. This method is not routinely applied in the UK but is included for comparison.

**UK Social Damage Costs:** Based on the damage which the pollution removed by the trees would otherwise cause. For further explanation of the difference between the US externality costs (USEC) and the UK social damage costs (UKSDC) see Appendix 1.
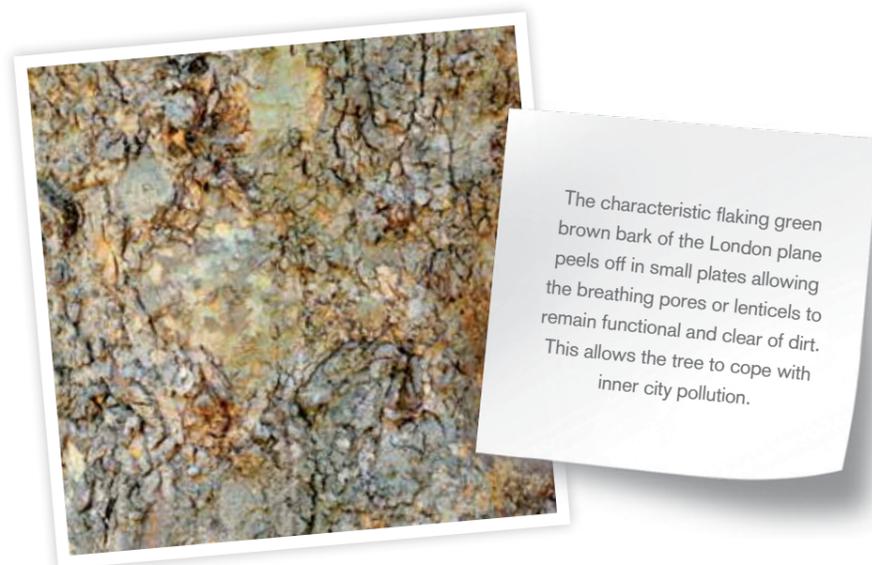
**Carbon storage:** The amount of carbon bound up in the above-ground and below-ground parts of woody vegetation

**Carbon sequestration:** The removal of carbon dioxide from the air by plants through photosynthesis

**Storm Water Attenuation:** Based on Carbon and energy savings using the Green Infrastructure Valuation Toolkit (GIVAT)[2]

**CTLA:** Council of Tree and Landscape Appraisers - A theoretical structural value based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree).

**CAVAT:** Capital Asset Value for Amenity Trees- 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.

→

The characteristic flaking green brown bark of the London plane peels off in small plates allowing the breathing pores or lenticels to remain functional and clear of dirt. This allows the tree to cope with inner city pollution.

## KEY FINDINGS

Existing trees, green spaces and other green infrastructure assets in Victoria divert up to 112,400 cubic metres of storm water runoffs away from the local sewer systems every year. This is worth between an estimated £20,638 and £29,006 in reduced $CO_2$ emissions and energy savings every year.

The total structural value of all trees in Victoria, (which does not constitute a benefit provided by the trees, but rather a replacement cost) currently stands at £2,103,276.

The trees in Victoria remove a total of 1.2 tonnes of pollutants each year and store 847.08 tonnes of carbon.

London plane currently dominates the treescape within Victoria BID, storing 59% of all carbon, filtering 67% of all pollutants and making up 29% of the tree population. However the London planes represent an ageing population and in order to maintain the current level of tree benefits to Victoria BID more trees capable of attaining a larger stature will need to be planted.

When implemented, the green infrastructure opportunities identified by Victoria BID have the potential to:

- Divert up to 67,500 additional cubic meters of storm water runoff every year, representing an estimated extra £12,392 in avoided $CO_2$ emissions and £17,417 in energy savings annually. Future design choices – particularly in relation to green roofs – will have a determining impact on the scale of water management benefits realised.

- Reduce peak summer surface temperatures by up to 5.1°C in the area surveyed. This will moderate local air temperatures, helping to ensure that the BID remains an attractive and comfortable environment for residents, visitors and workers alike. It will also reduce the need for air conditioning in office buildings, lowering energy costs and carbon emissions.

- The high CAVAT value of 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 below.

| KEY FINDINGS | | | |
|---|---|---|---|
| NUMBER OF TREES | 1,225 | | |
| CANOPY COVER | 8.8% | | |
| SPECIES RECORDED | 139 | | |
| MOST COMMON SPECIES | London plane, Pear (Chanticleer) and Cherry | | |
| AVERAGE STEM DIAMETER (DBH) | 38cm | | |

| | Amount (tonnes) | US Externality Costs (USEC) | UK Social Damage Cost (UKSDC) |
|---|---|---|---|
| POLLUTION REMOVAL (PER YEAR) | 1.2 | £5,998 | £85,149 |

| | Amount | Value | |
|---|---|---|---|
| CARBON STORAGE | 847.08 tonnes | £44,895.24 | |
| CARBON SEQUESTRATION | 18.35 tonnes | £972.55 | |
| STORM WATER ATTENUATION | 112,400 m³ | £49,644.00 | |
| CTLA REPLACEMENT COST | £2,103,276.00 | | |
| CAVAT VALUE | £27,245,046.00 | | |

# CONTENTS ▶

## INTRODUCTION

The trees which make up the urban forest positively influence human health and well-being by providing a range of benefits or eco-system services. Recognising and estimating these benefits can assist in making the right decisions about how trees are managed.

For example, urban forests help to combat the effects of climate change. Projections for climate change claim that summers are going to be warmer and dryer, accompanied by wetter winters, with more frequent extremes of temperature (Hulme et al., 2002). Trees not only lower the ambient temperature in their microclimate through evaporative cooling but are also effective at retaining storm water and therefore alleviating pressure on drainage systems (Gill et al 2007).

The trees in the Victoria Business Improvement District (BID) are a key component of this urban forest infrastructure, providing a wealth of benefits, offering resilience against climate change impact, protecting urban communities against the extremes of the urban heat island effect and temperature increases. Crucially they provide shade, evaporative cooling, pollution filtration and also capture and store carbon (Nowak 2006).

Given the importance of the urban tree resource, knowledge of the contribution that trees make needs to be available for strategic planning and management. This requires that key information be gathered so that the resource can be protected and enhanced, and its crucial functionality maintained.

By measuring these ecosystem services a baseline can be established from which to monitor change over time and also spatially. By formulating a reliable means of measuring the natural tree resource it is possible to manage urban trees in a way that secures the existing services they provide and then to strategically enhance these in order to achieve sustainability aspirations.

## METHODOLOGY

During the summer of 2011 a trained field crew worked together with volunteers from the Trees for Cities project to record details on all publicly and privately owned trees within the Core and Buffer zones of Victoria's Business Improvement District (see figure one, on following page).

Details on tree species and location were recorded, as well as field measurements to assess the size, species and condition of the trees.

Many privately owned trees were also recorded within the study to capture the total benefit that trees provide to the local area. However, a small proportion of inaccessible privately owned trees could not be measured.
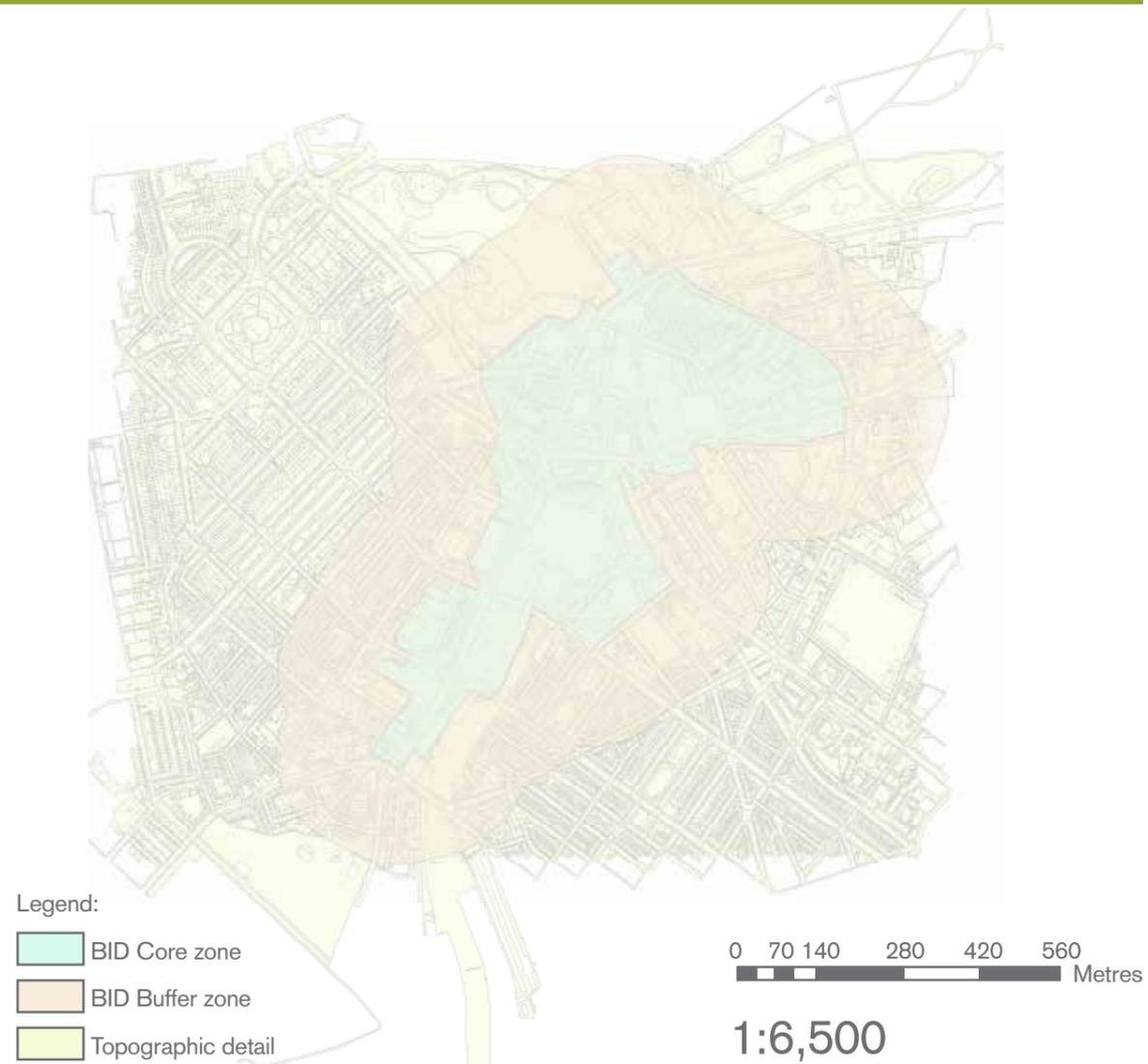
Using aerial imagery and Geographical Information System (GIS) together with the field data, the amount of privately owned trees that could not be assessed was in the region of 1-10%.

The collected field measurements were processed along with local pollution and climate data using the i-Tree Eco[3,4] model to provide the results contained within this report.

The Green Infrastructure Valuation Toolkit (GIVAT)[5] was also used as a companion to the i-Tree Eco assessment. This was undertaken in order to quantify the water management and temperature moderation benefits associated with green infrastructure in the Victoria Business Improvement District.

Similarly, the Capital Asset Valuation for Amenity Trees (CAVAT)[6] was applied to the field data and additional field visits to provide an amenity valuation for the trees.

3. For further details on how the i-Tree Eco model is applied to the UK context see Rogers et al (2011)
4. For further details on i-Tree Eco see: www.i-treetools.org

5. For further information see: www.greeninfrastructurenw.co.uk/html/index.php?page=projects&GreenInfrastructureValuationToolkit=true
6. For further information see: www.ltoa.org.uk/resources/cavat

**FIG 1:** MAP OF STUDY AREA SHOWING THE CORE ZONE AND BUFFER ZONE

Legend:

- BID Core zone
- BID Buffer zone
- Topographic detail

0   70 140      280       420       560
Metres

1:6,500

As well as quantifiable benefits trees also soften the hard landscape, improve the character of our urban areas and provide shade.

# TREE CHARACTERISTICS

**Tree Species**
Figure 2 shows the most common tree species as percentages of the total population. In total 1225 trees were recorded in this survey (Core zone 230 trees, Buffer zone 995 trees), of which London plane accounts for 29% of the total population. Callery (Chanticleer) Pear is the second most common tree species at 7%, followed by Cherry with 5%. Figure 2 shows the percentage of population for the ten most common tree species recorded in the study.
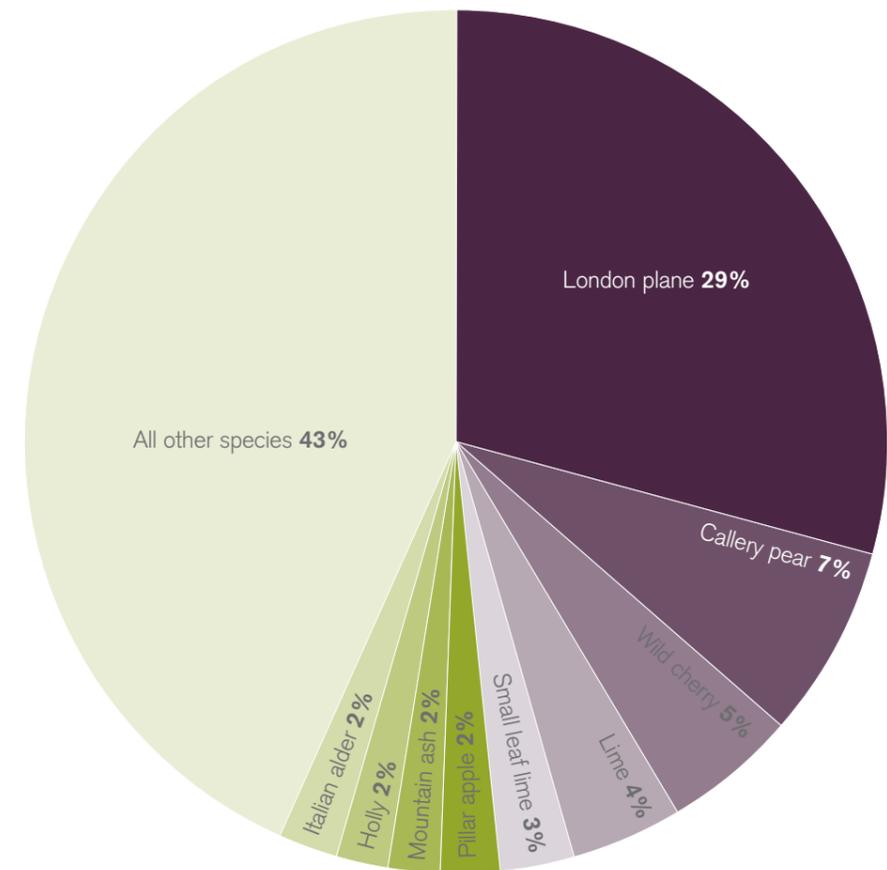


London plane **29%**

All other species **43%**

Callery pear **7%**

Wild cherry **5%**

Lime **4%**

Small leaf lime **3%**

Pillar apple **2%**

Mountain ash **2%**

Holly **2%**

Italian alder **2%**

**FIG 2:** PERCENTAGE POPULATION OF TREE SPECIES

# TREE DIVERSITY

Victoria BID's tree diversity is an important element of the urban tree population as diversity increases overall resilience in the face of various stress inducing factors. A more diverse treescape is better able to deal with possible changes in climate, the effects of increased pollution or the outbreak of disease. The tree population in Victoria BID is a very diverse community given its size, with 139 species of tree (from 61 Genera) identified[7].

**Size Distribution**
Size class distribution is also an important factor in managing a sustainable tree population, as this will ensure that there are enough young trees to replace those older specimens that are eventually lost through old age or disease. In this survey trees were sized by their stem diameter at breast height (DBH) at 1.3m. Figure 3 shows the percentage of tree population by DBH class.
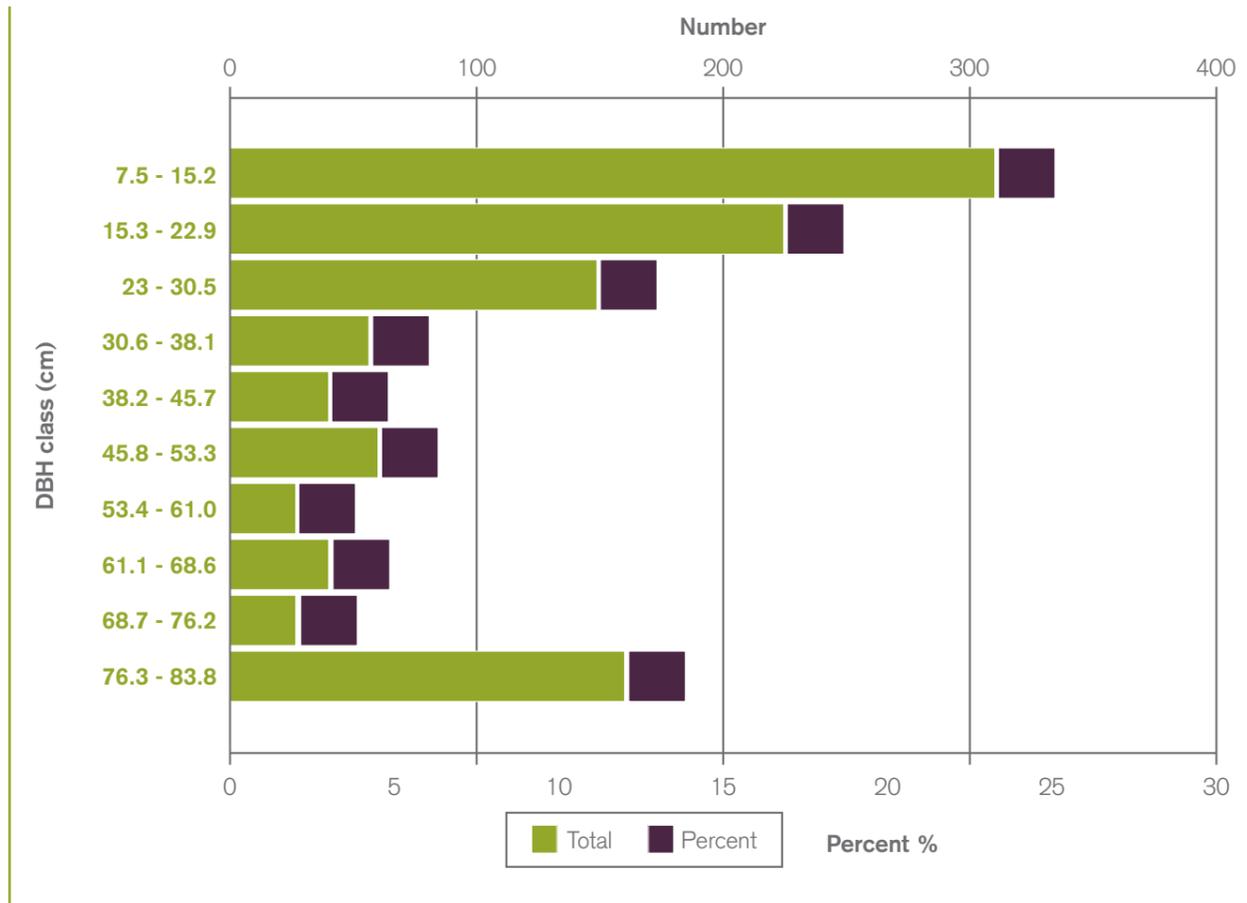
**FIG 3:** PERCENTAGE DBH CLASS



**FIG 4:** DBH BY CLASS AND SPECIES

Those trees with smaller stem diameters (less than 15.2cm) constitute 26% of the total population. Trees with stems greater than 61.1cm represent 20% of the population. The most common stem class for trees measured in Victoria fall within 15.3 to 30.5cm category (30%).

This represents an uneven range of sizes with fewer medium sized trees in the population to replace the larger trees as they grow old and die.

If new plantings are predominantly composed of smaller stature species, total canopy cover will decline over time, especially if larger species are not replaced with trees of similar characteristics. The results of this study serve to illustrate how the planting of smaller stature trees has increased those lower diameter classes but that the mid range remains low as nothing 'grows into' this range. If Victoria BID wishes to maintain its tree cover and tree benefits at current levels then more trees capable of attaining a larger size will need to be planted to ensure that there is no shortfall in the future.

The stem diameter classes for the ten most common tree species within Victoria BID are shown in figure 4.

As might be expected, the greatest numbers of Holly, Cherry and Pear are mostly represented in the lower DBH classes. London plane on the other hand (representing 29% of the tree population) represents 57% of all the trees over 61cm stem diameter.
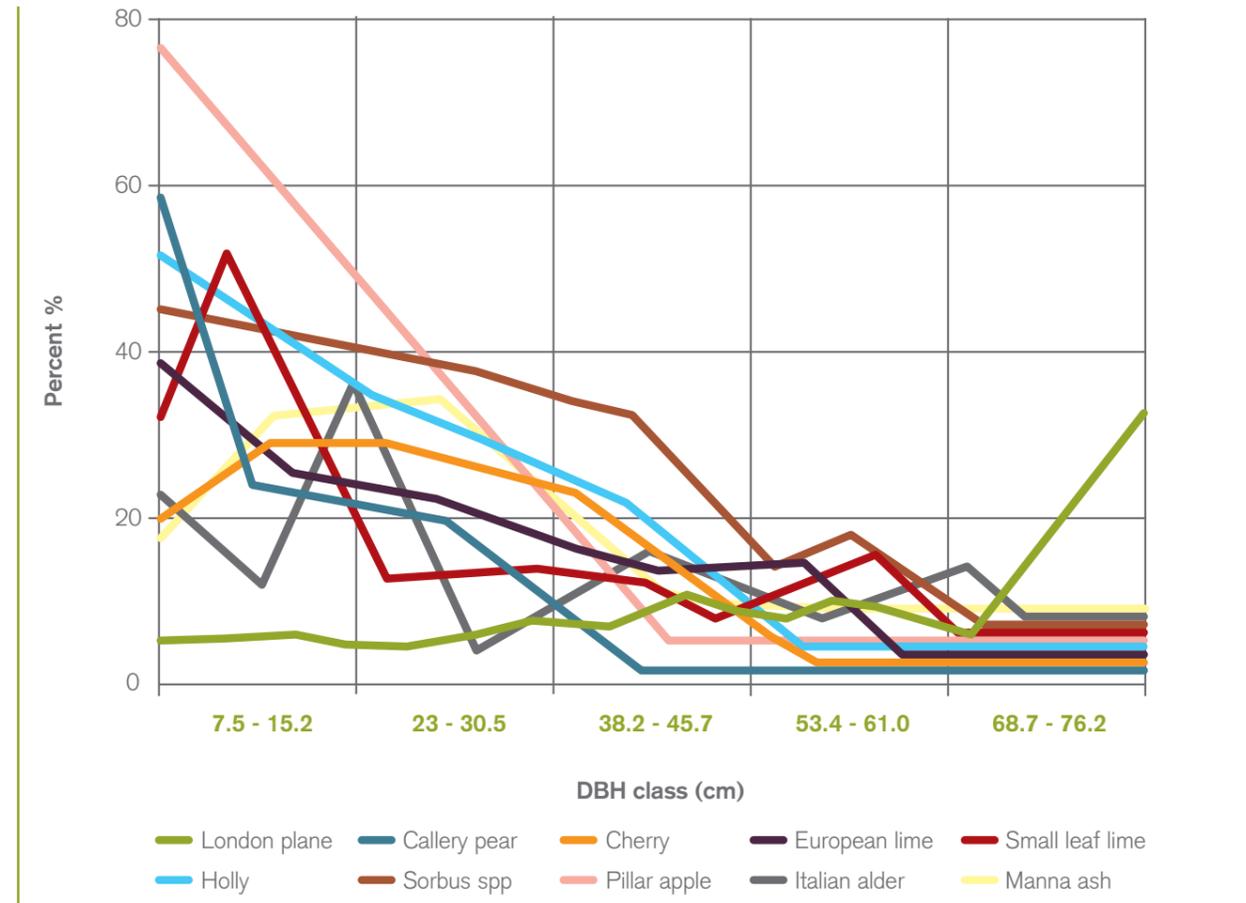
**Importance Value**

Within the i-Tree Eco model leaf area, values are combined with species population data to provide an importance value (IV) for each tree species. However, a high IV 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.

These species currently dominate the urban treescape and are therefore the most important in delivering environmental benefits. The 10 most important tree species are shown in figure 5.

The London plane is by far the most dominant tree in Victoria with an importance value score of 97, over 10 times the value of Callery pear (with an importance value of 7.9 and the second most important tree in Victoria). Table 1, on the following page contains the figures which are represented in figure 5.
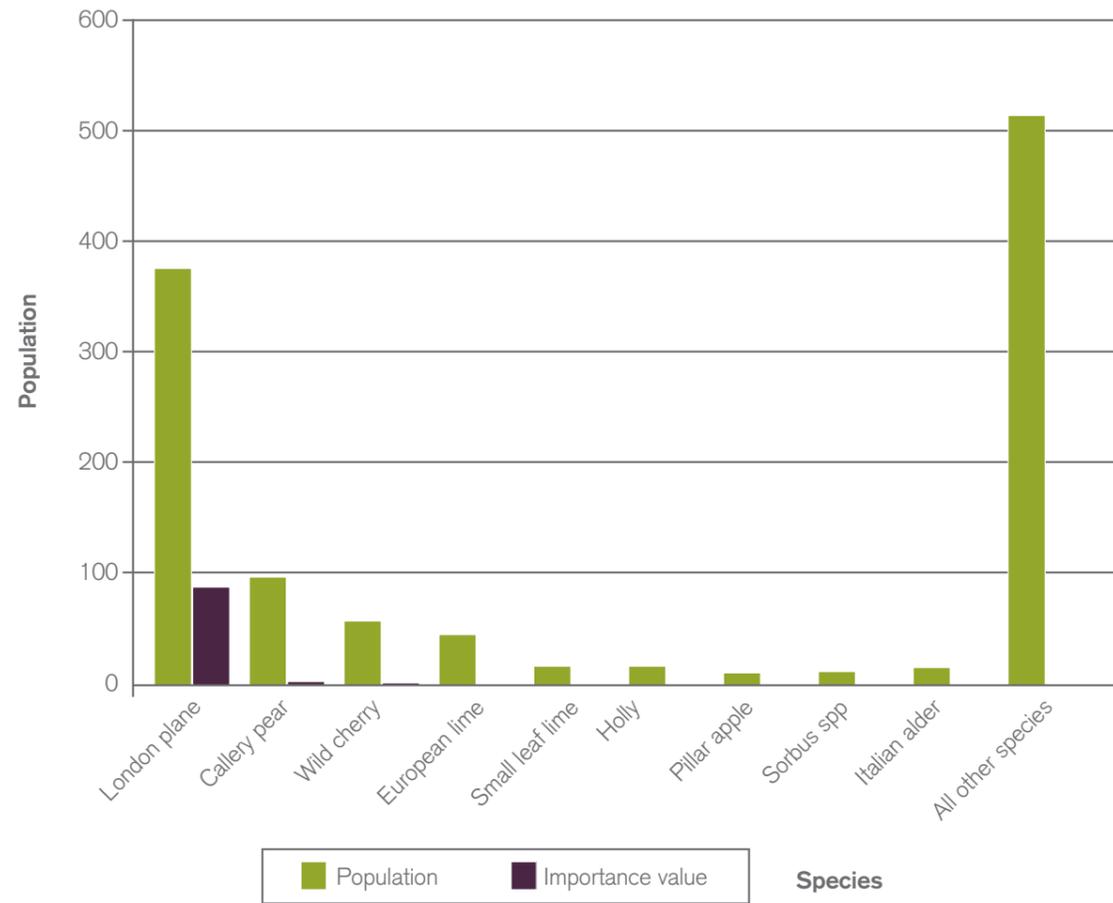
The planes of Grosvenor Gardens provide a fantastic amenity for people to relax, have lunch or socialise.

Population (y-axis: 0, 100, 200, 300, 400, 500, 600)

Species (x-axis): London plane, Callery pear, Wild cherry, European lime, Small leaf lime, Holly, Pillar apple, Sorbus spp, Italian alder, All other species

■ Population   ■ Importance value

**FIG 5:** IMPORTANCE VALUE OF THE TEN MOST SIGNIFICANT TREE SPECIES

## TEN MOST COMMON TREE SPECIES

| SPECIES | POPULATION | IMPORTANCE VALUE |
| --- | --- | --- |
| LONDON PLANE | 360 | 97.08 |
| CALLERY PEAR | 84 | 7.92 |
| WILD CHERRY | 62 | 7.71 |
| EUROPEAN LIME | 48 | 5.63 |
| SMALL LEAF LIME | 38 | 4.44 |
| HOLLY | 32 | 3.42 |
| PILLAR APPLE | 27 | 3.26 |
| SORBUS SPP | 27 | 3.12 |
| ITALIAN ALDER | 26 | 3.00 |
| ALL OTHER SPECIES | 528 | 2.92 |

**TABLE 1:** IMPORTANCE VALUE AND POPULATION OF THE TEN MOST SIGNIFICANT TREE 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 ability to capture airborne pollutants.

**Leaf Area**
In the Victoria BID, total leaf area is estimated at 3.7 hectares (373,387 m²). The total study area is 1,258,251m². If all the layers of leaves within the tree canopies were spread out they would cover 29% of the Victoria BID area.

The three most dominant species in terms of leaf area are London plane (67%), Cherry (2.6%) and Horse chestnut (2.1%). Figure 6 shows the most dominant trees contributions to total leaf area. In total these 10 species (representing 707 trees) contribute 77% of the total leaf area. The remaining 518 trees provide the other 33% of canopy cover.

The London planes provide more than twice the leaf area of all other tree species combined, making them particularly important for providing benefits to Victoria BID.



One of the 8 Indian Bean Trees recorded in the survey. Collectively this species stores 6.2 tonnes of carbon within the Victoria BID



Population (y-axis: 0, 25, 50, 75, 100)

(x-axis): London plane, Callery pear, Wild cherry, European lime, Small leaf lime, Horse chesnut, Norway maple, Italian alder, Holly, Pillar apple

■ Species %   ■ Leaf area %

**FIG 6:** PERCENTAGE LEAF AREAS OF THE 10 MOST COMMON TREES

## Canopy Cover

Tree canopy cover (TCC), also referred to as canopy cover and urban canopy cover, can be defined as the [combined] layer of leaves, branches, and stems of trees that cover the ground when viewed from above (Grove et al 2006). TCC is a two dimensional metric, indicating the spread of canopy cover across a given area, and whilst related to, it is not the same as Leaf area or Leaf Area Index (LAI). At the most basic level TCC can tell us how much tree cover there is in a particular area and highlight available opportunities to plant more trees (Rodbell and Marshall 2009).

Tree Canopy Cover for Victoria BID was calculated using the direct field measurements at 8.8% (110447 m²) and using GIS at 9.4% (118155 m²). These findings are consistent with those reported in Trees in Towns 2 for other UK urban areas (Britt and Johnston 2008). The small disparity between the two figures (at 0.6%) may in part be due to the fact that not all of the trees on private property could be accessed during the study.
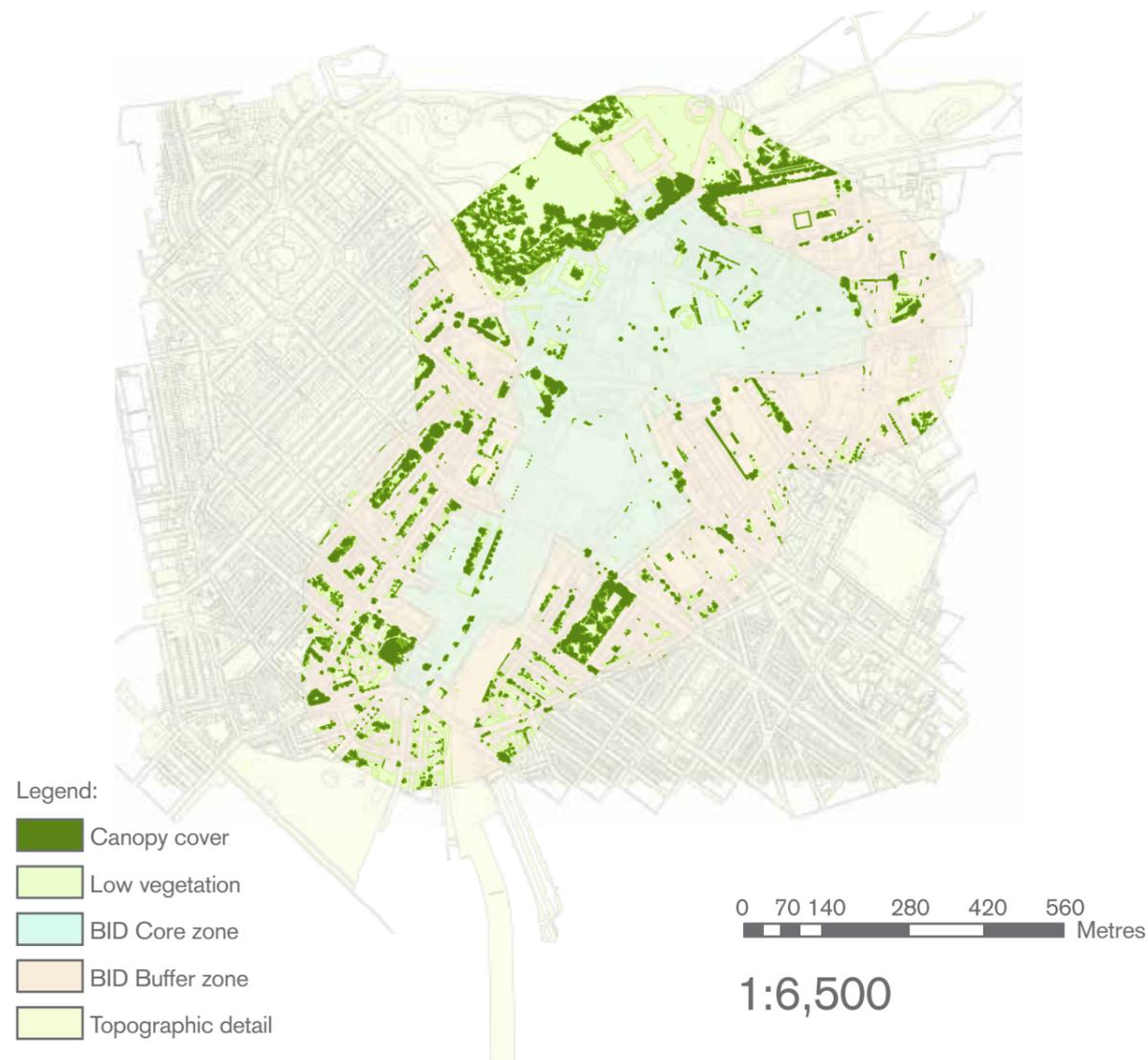


Legend:
- Canopy cover
- Low vegetation
- BID Core zone
- BID Buffer zone
- Topographic detail

0  70  140    280    420    560
Metres

1:6,500

**FIG 7:** VICTORIA BID CANOPY COVER MAP

---

## Background

Poor air quality is a common problem in many urban areas with significant implications for human health and wellbeing. For example, air pollution contributes to asthma and respiratory heart disease from harmful particulate emissions that are sufficiently small to pass through the lining of the lung (PM10s and smaller).

Urban Trees can help to improve air quality by reducing air temperature and directly removing pollutants from the air (Tiwary et al 2009). They also intercept and absorb airborne pollutants through leaf surfaces (Nowak et al 2000). By removing pollution from the atmosphere trees reduce the risks of respiratory disease and asthma, thereby contributing to reduced health care costs (Peachet et al 2009, Lovasi et al 2008).

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 (Nowak et al 2006). Since different tree species may emit VOCs at different levels species choice is an important consideration. Donovan ((2003) quoted in McDonald et al (2007)) developed an Urban Air Tree Quality Score as a decision support tool for this purpose.

## Annual Pollution Removal

Figure 8 shows the amount of pollution removed each year and the value of this benefit using the UK social damage (UKSDC) and US externality costs (USEC). USEC figures are given for comparison, see Appendix 1 for more detailed information.

The trees in Victoria remove a total of 1.2 tonnes of pollutants each year, equating to a US externality cost of £5,998/yr. This value increases to £85,149/yr if the UK social damage costs are used.
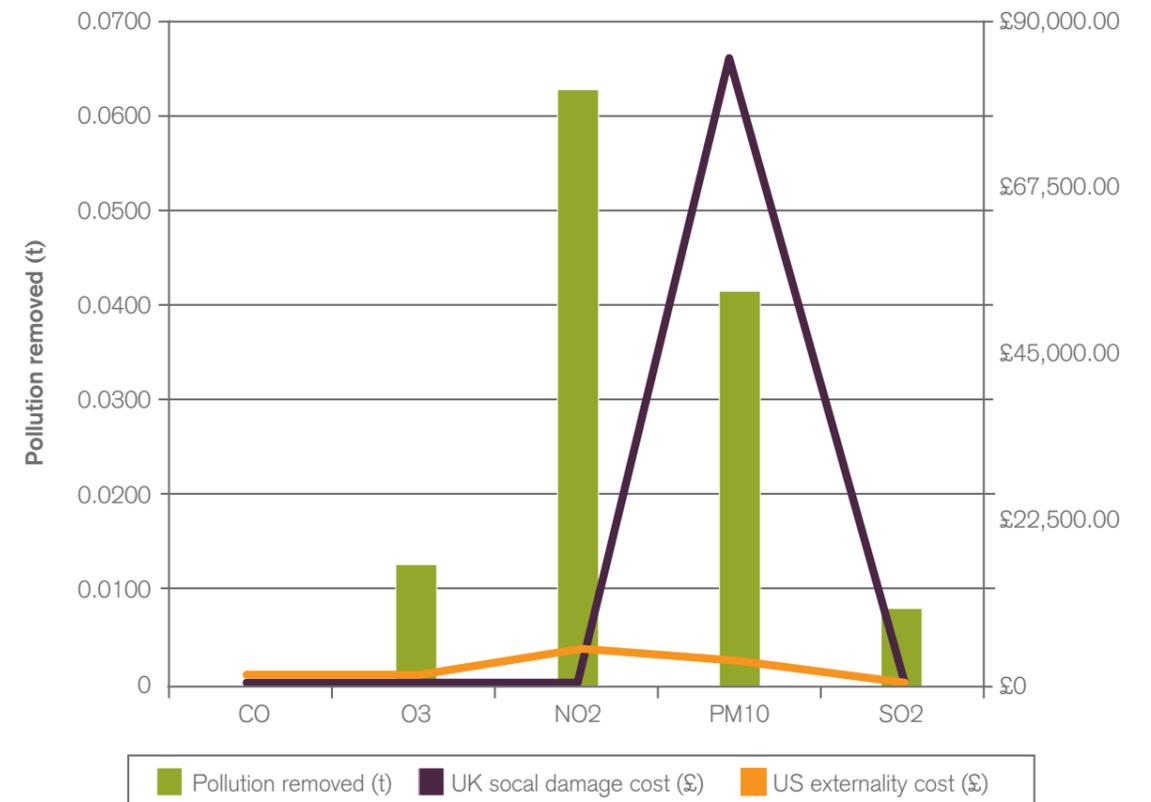


**FIG 8:** TOTAL YEARLY POLLUTION REMOVAL

A Black locust (Robinia pseudoacacia) at the Parish of St Peters Church, Hobart Place. This tree has a leaf area of 305 m2, allowing the tree to sequester around 43kg of carbon every year.

**Pollution Removal by Individual Trees**

Figure 9 (above) shows the breakdown for the top ten pollution removing trees in Victoria. As different species can capture different sizes of particulate (Freer-Smith et al 2005) a broad range of species should be considered for planting in any air quality strategy.

The chart clearly shows that although Callery pear is the second most common species (84 trees) it is superseded by 8 other less populous species which filter more pollutants. For example the 2 Cedars recorded filter more pollutants than the combined effects of these 84 Callery pears. The London planes (360 trees) remove more than 4.5 times the amount of pollutants than the rest of the top ten trees combined (344 trees).

Pollution removal is greatest for nitrogen dioxide (NO2) followed by PM10s, which have the greatest social cost according to figures from the Interdepartmental Group on Costs and Benefits (IGCB) based on DEFRA, 2007. Carbon monoxide removal is negligible because amounts of CO recorded were low. This finding is consistent with other UK studies.

# CARBON STORAGE AND SEQUESTRATION

**Climate Change**

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 sequestering atmospheric carbon as part of the carbon cycle. Trees are comprised of around 50% carbon and tree stems and roots act as a long-term store of carbon because these woody structures can last for centuries.

**Carbon Storage**

Overall the trees in Victoria store 847.08 tonnes of carbon with a value of £44,895. Figure 10 illustrates the carbon storage of the top ten trees along with the value of the carbon they contain.

**Carbon Sequestration**

Carbon sequestration is calculated from the predicted growth of the trees based on the field measurements and the 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. The current UK social cost is £53/tonne (DECC 2009).

Victoria's trees annually sequester 18.35 tonnes of carbon per year, with a value of £972.55. Figure 11 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.

As trees die and decay most of the carbon that was once stored in the wood is released back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be lost if the trees were allowed to die and decompose.
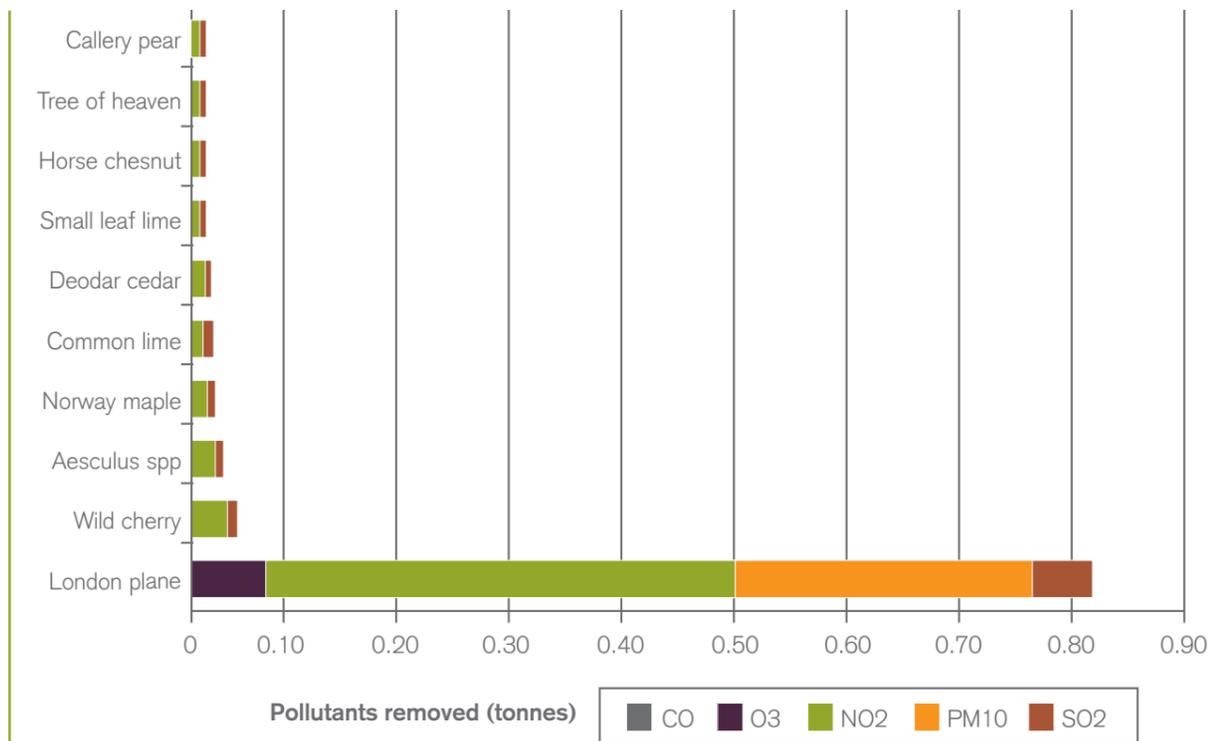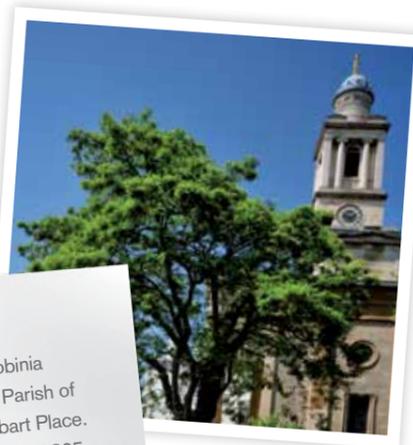
Of all the tree species inventoried London plane stores and sequesters the most carbon, adding nearly 10 tonnes every year to the current carbon storage of London planes of 662 tonnes. This represents 78% of total carbon stored by the entire tree stock and is a reflection of the size and population of the plane trees. Figure 12 shows the percentage distribution of the carbon sequestered in Victoria's tree stock.



Carbon sequestered ◼ Value
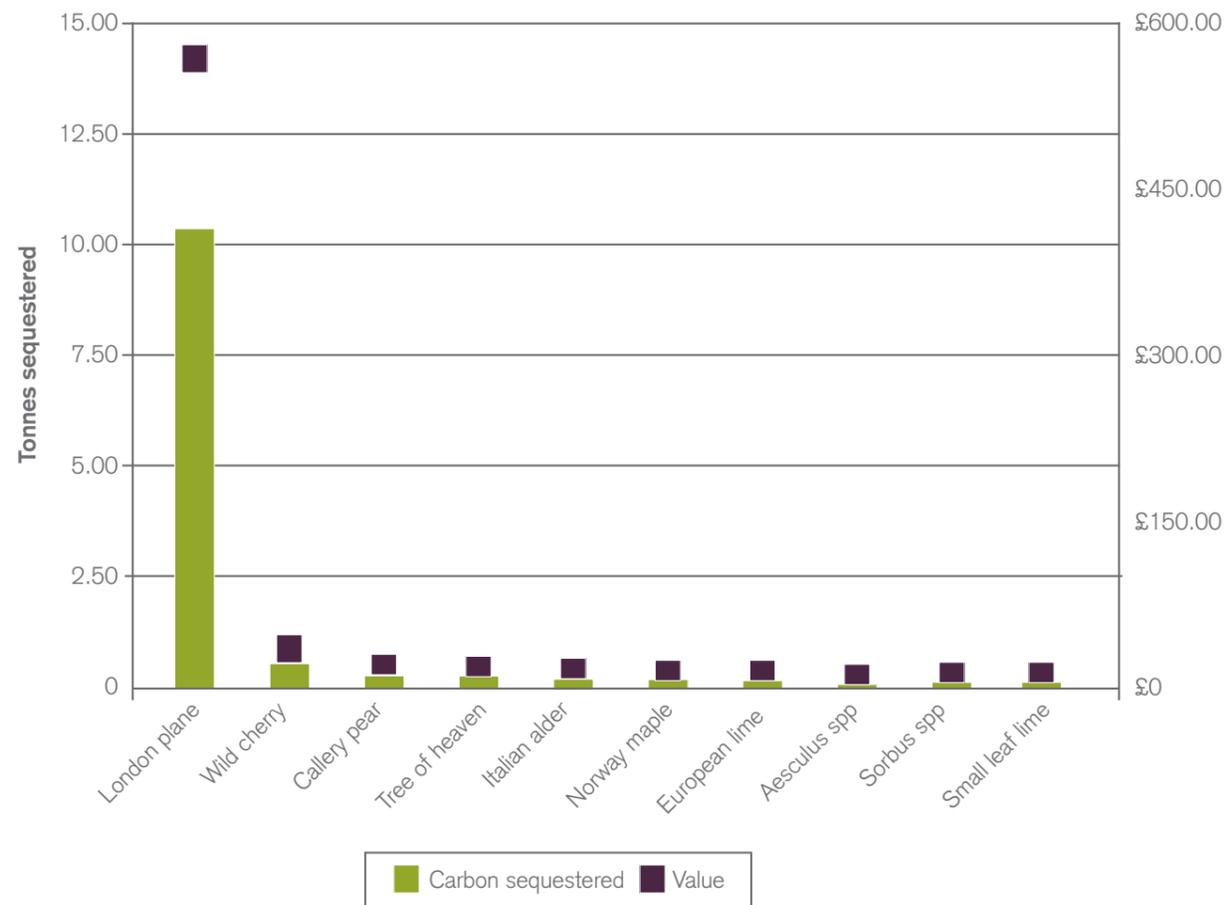
**FIG 11:** PERCENTAGE AND VALUE OF CARBON SEQUESTERED IN THE TOP TEN TREES



Where trees are located within parks the other greenspace also contributes towards reducing the urban heat island effect and reducing stormwater runoff.

**FIG 12:** CARBON SEQUESTERED BY TREE SPECIES



All other species **24%**

Small leaf lime **1%**
Aesculus spp **1%**
Sorbus spp **1%**
European lime **2%**
Norway maple **2%**
Italian alder **2%**
Tree of heaven **2%**
Callery pear **2%**
Wild cherry **4%**

London plane **59%**



Studies (such as those by Wolf 2005) have shown that shoppers spend longer and spend more in leafier environments. They also attract better businesses and therefore higher paid workers.

# STORM WATER MANAGEMENT AND SURFACE TEMPERATURE MODERATION BY GREEN INFRASTRUCTURE

**Background**

The Green Infrastructure Valuation Toolkit provides a flexible framework for identifying and scoping the potential economic and wider returns from investment in natural assets and landscape improvements. Further details on the background are reproduced in Appendix 4.

Rather than applying the Toolkit in its entirety, only relevant (climate change adaptation and mitigation and water management) modules were used. These were:

• Tool 1.4 Reduction in peak surface temperatures.

• Tool 2.1 Energy and $CO_2$ emissions savings from reduced volume of storm water entering combined sewers.

Each tool was applied to estimate the impact of current green infrastructure provisions, as well as to scope benefits associated with the proposed green infrastructure investments.

**Green infrastructure baseline and development scenario for Victoria**

Information on the Victoria BID's existing and potential green assets were sourced from:

• The Green Infrastructure Audit conducted by LUC and The Green Roof Consultancy in 2010.

• The tree audit data conducted for the i-Tree eco assessment by Treeconomics.

• Ground truthing and further GIS analysis conducted by the Victoria BID and its partners, including The Green Roof Consultancy and Treeconomics.

Figures for potential green infrastructure investments are based on:

• Ground level green space opportunities: findings from the Green Infrastructure Audit.

• Canopy: the Mayor of London's target to increase canopy cover in London by 5% by 2025. Detailed canopy growth analysis and modelling will be needed to confirm whether the current age and species profile characterising the local urban forest combined with the tree planting plan set out by Westminster City Council will allow the long term delivery of this objective.

• For potential green roofs: findings from the GIS analysis led by Treeconomics, based on the audit led by The Green Roofs Consultancy. The distribution between intensive, semi-intensive, and extensive green roofs is based on the surface percentage breakdown detailed in the Green Infrastructure Audit.

**Reduction in peak surface temperatures**

The larger and the more densely built urban environments become, the warmer they tend to be in comparison to the surrounding countryside. This phenomenon, known as the urban heat island effect, is likely to exacerbate temperature rises resulting from climate change. The warming of the urban environment is an important issue because of its implications for air quality, human comfort and health, building energy use and water consumption.

Mapping conducted in preparation for the Mayor of London's climate change strategy, Managing Risks and Increasing Resilience show that Central London, including Victoria BID, is significantly affected by climate change impacts.

Green infrastructure such as parks, green roofs and street trees provide an effective solution for moderating urban temperatures. Trees and shrubs provide protection from heat by direct shading of buildings and outdoor spaces. Vegetation and soils also cool the air around them by diffusing moisture. On figure 13 the yellow shaded areas indicate lower surface temperatures, which match the key green spaces located on the boundaries of the Victoria BID. This offers a good illustration of the effect of green infrastructure at lowering local temperatures.

To estimate the impact of green infrastructure on temperature, the ASCCUE[8] project (led by the University of Manchester five years ago) applied a model developed by Whiteford et al. that uses surface temperatures as an indicator for energy exchanges in the urban environment. Applied to Greater Manchester, the model expressed peak summer surface temperature as a function of the local evaporative fraction – i.e. the proportion of green and blue spaces that evapo-transpire.

|  | EXISTING (HA) | PROPOSED (HA) |
|---|---|---|
| GROUND LEVEL GREEN SPACES | 20.75 | +1. 25 |
| GREEN ROOFS INCLUDING: EXTENSIVE SEMI-INTENSIVE INTENSIVE | 0.40 0.40 0.00 0.00 | +17.66 +14.51 +3.27 +0.28 |
| TREE CANOPY (73% IS CURRENTLY OVER GROUND LEVEL GREEN SPACE) | 11.82 | +12.41 |
| TOTAL GREEN COVER | 24.37 | +19.50 |

**TABLE 2:** EXISTING AND PROPOSED GREEN INFRASTRUCTURE
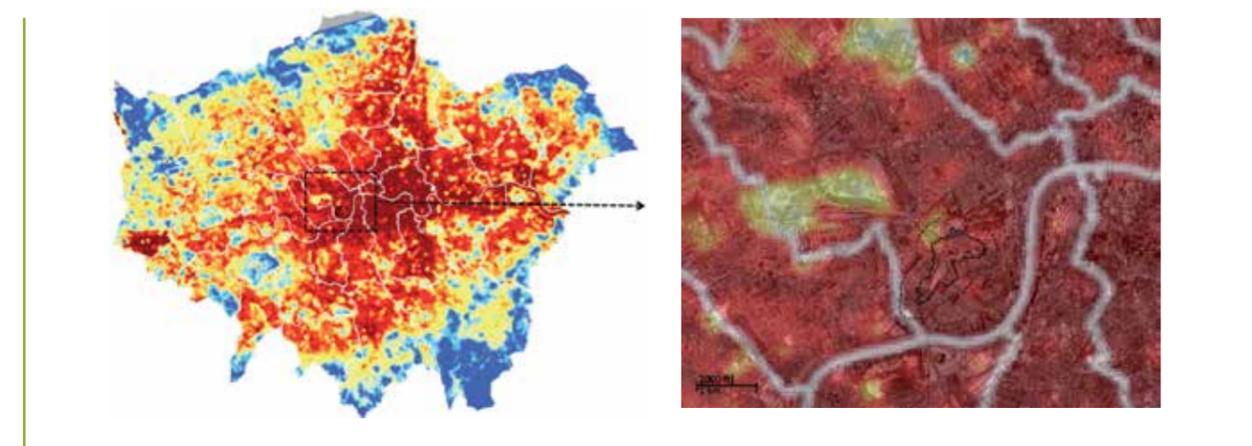


**FIG 13:** LAND TEMPERATURE, 12 JULY 2006, 21.00 UT ASTER SATELLITE IMAGE WITH VICTORIA BID BOUNDARY

Figure 14 illustrates this effect. With 23 percent green cover, peak surface temperatures reach 32°C. The creation of 10 percent new green cover, for example via a green roof or a street tree planting programme – reduces peak summer temperatures to 29°C. Reducing green space by 10 percent, through development, or lack of foresight in replacing ageing large canopy trees will reduce cooling and the surface temperature could rise to 35°C.

Results from the Manchester based modelling conducted by ASCCUE are used as a basis for tool 2.1 to provide estimates of the impact of variation in green cover over surface temperatures for other urban areas.

### FINDINGS

• Once implemented, the proposed green infrastructure investments in Victoria will increase the area's green cover by 80%. This will bring the evaporative fraction from 0.19 to 0.35; a very significant improvement.

• Tool 1.4 of the Green Infrastructure Valuation Toolkit shows that this dramatic change could lower peak surface summer temperatures by up to 5.1°C.
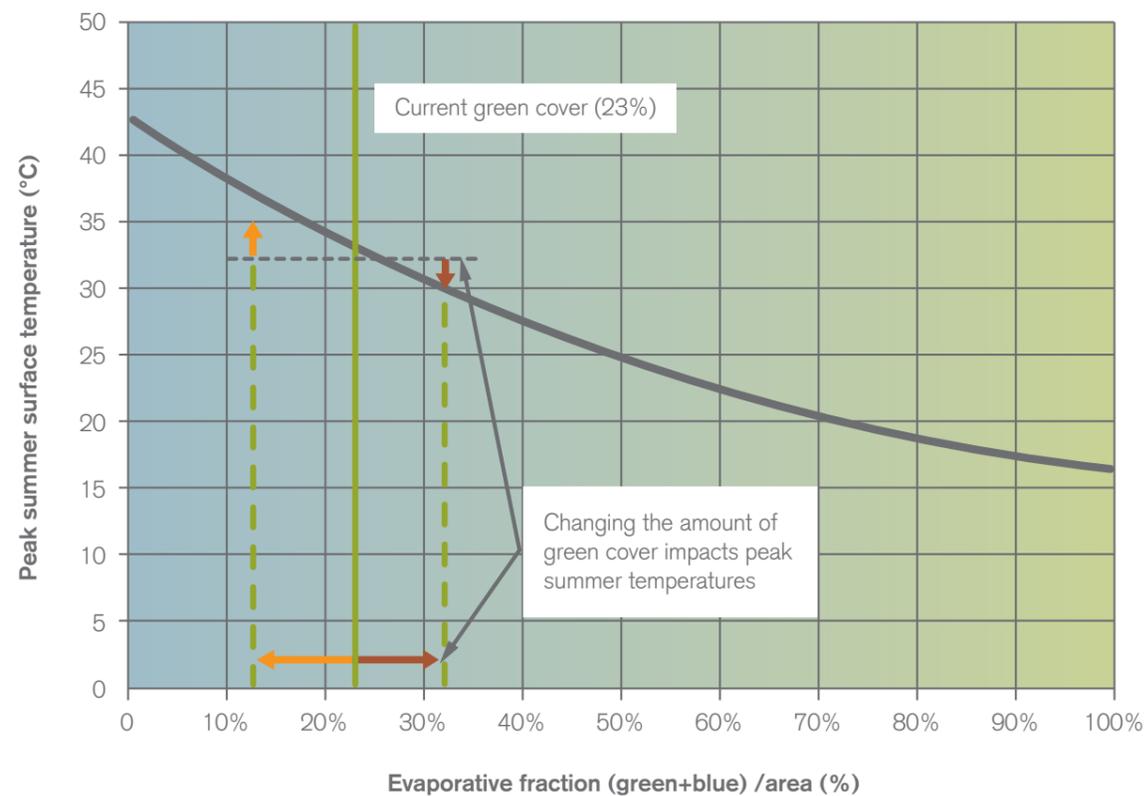


Current green cover (23%)

Changing the amount of green cover impacts peak summer temperatures

Peak summer surface temperature (°C)

Evaporative fraction (green+blue) /area (%)

**FIG 14:** RELATION BETWEEN EVAPORATIVE FRACTION AND PEAK SURFACE TEMPERATURES

# ENERGY AND CO² EMISSIONS SAVINGS FROM REDUCED VOLUME OF STORM WATER ENTERING COMBINED SEWERS

In older urban centres serviced by combined sewer systems, such as Victoria, large areas of impermeable surfaces create a heavy reliance on underground pipe systems and associated wastewater treatment facilities for managing storm water runoff. This presents a number of problems:

• Most combined sewer systems were not designed to accommodate the peak flows resulting from the largely impermeable surfaces that now prevail in city centres, resulting in increasing surface water flooding issues. These cause damage to both buildings and infrastructure, in addition to posing some serious threats to public health and safety. Climate change is further aggravating this, generating larger volumes of storm water over shorter periods of time.

• By design, combined sewers treat both storm water runoff and wastewater from buildings in the same way. This is despite a large proportion of storm flows not requiring as intense a treatment as building effluents. This generates a rather significant and largely wasteful consumption of resources, such as pumping and treating water which requires significant amounts of energy.

It is on this relationship between water and energy, sometimes described as 'watergy', that tool 2.1 of the Toolkit focuses. This tool helps assess the impact of vegetation on lowering the amount of rainfall entering the combined sewers, based on:

• Water interception by trees, the process by which water held on the surface of leaves, branches and trunks during and after rainfall is directly evaporated back into the atmosphere. Studies conducted in the UK in forest environments have shown interception rates ranging from 10 to 25 percent (Calder et al 2003). Using these values in an urban context is not entirely satisfactory because both tree morphology and microclimates differ quite significantly in built-up environments. Recent studies conducted in Canada (Asadain and Weiler 2009) have demonstrated that urban trees interception performance can significantly exceed that of similar counterparts in forest environments. However, in the absence of available canopy interception data for the

UK, the UK broadleaves forest interception values provide the next best available option for tool 2.1.

• Storm water runoff attenuation by grassland and other low vegetation in parks. This is estimated using average runoff coefficient values – also known as 'C' values - recommended by the American Society of Civil Engineers and the Water Environmental Federation in its 1992 manual Design and Construction of Urban Storm water Management Systems, as part of what is widely known as the 'Rationale Method'. For parks and playgrounds in heavy soils, these recommended 'C' values ranged from 0.25 to 0.35. Tool 2.1 is therefore designed on the basis of a 65 to 75 percent attenuation effect by grassland and other low vegetation in parks.

• Storm water runoff attenuation by green roofs. Tool 2.1 uses the storm water attenuation values recommended by the Green Roof Consultancy based on available research. These are: 45 to 55 percent of annual rainfall for extensive green roofs, 60 to 65 percent of annual rainfall for semi-intensive green roofs and 90 to 100 percent of annual rainfall for intensive green roofs.

Tool 2.1 then estimates the economic value of the storm water attenuation benefit generated by green infrastructure based on the average energy consumed by water companies for water treatment (645 kWh per megalitre of waste water treated[8]), the cost of energy, the social value of carbon (£53/tC, updated for inflation[9]) and the carbon intensity for grid electricity (0.537kg/kWh[10]).

### FINDINGS

Existing trees, green spaces and other green infrastructure assets in Victoria were estimated to divert between 89,100 and 112,400 cubic metres of storm water runoffs away from the local sewer system every year. This was found to be worth up to £20,638 in reduced $CO_2$ emissions savings and £29,006 in energy savings every year.

When implemented, the proposed green infrastructure improvements have the potential to divert up to 67,500 cubic meters of storm water runoff every year, representing an estimated extra £12,392 in avoided $CO_2$ emissions and £17,417 in energy savings annually.

9.  Source: Sustainable Water, State of the Water Sector Report, Water UK, 2008
10. Source: Carbon Valuation in UK Policy, DECC, 2010
11. Source: Defra / Carbon Trust, 2008

| | GROUND LEVEL GREEN SPACE | TREE CANOPY | EXTENSIVE GREEN ROOF | SEMI INTENSIVE GREEN ROOF | INTENSIVE GREEN ROOF | TOTAL |
|---|---|---|---|---|---|---|
| Interception ratio | Low (65%) High (75%) | Low (10%) High (25%) | Low (50%) High (55%) | Low (60%) High (65%) | Low (90%) High (100%) | Low High |
| **CURRENT CONDITIONS** | | | | | | |
| Water currently diverted from sewers (1/yr) | 80,925,000 93,375,000 | 7,092,000 17,730,000 | 1,080,000 1,320,000 | 0 0 | 0 0 | 89,097,000 112,425,000 |
| Equivalent current energy saving (kWhr/yr) | 521,966 602,269 | 45,743 114,359 | 6,966 8,514 | 0 0 | 0 0 | 574,676 725,141 |
| Equivalent current avoided $CO_2$ emissions saving ($tCO_2$/yr) | 280 323 | 25 61 | 4 5 | 0 0 | 0 0 | 309 389 |
| Value of current avoided $CO_2$ emissions saving (£/yr) | 13,713 17,141 | 1,302 3,255 | 198 242 | 0 0 | 0 0 | 15,213 20,638 |
| Value of current energy saving (£/yr) | 20,879 24,091 | 1,830 4,574 | 279 341 | 0 0 | 0 0 | 22,987 29,006 |
| **AFTER GI ENHANCEMENT** | | | | | | |
| Water diverted from sewers under proposed design (1/yr) | 85,800,000 99,000,000 | 7,446,000 18,615,000 | 39,177,000 47,883,000 | 11,772,000 12,753,000 | 1,512,000 1,680,000 | 145,707,000 179,931,000 |
| Equivalent energy saving under proposed design (kWhr/yr) | 553,410 638,550 | 48,027 120,067 | 252,692 308,845 | 75,929 82,257 | 9,752 10,836 | 939,810 1,160,555 |
| Equivalent avoided $CO_2$ emissions saving under proposed design ($tCO_2$/yr) | 297 343 | 26 64 | 136 166 | 41 44 | 5 6 | 505 623 |
| Value of avoided $CO_2$ emissions under proposed design ($tCO_2$/yr) | 14,539 18,174 | 1,367 3,417 | 7,192 8,790 | 2,161 2,341 | 278 308 | 25,537 33,030 |
| Value of energy under proposed design (£/yr) | 22,136 25,542 | 1,921 4,803 | 10,108 12,354 | 3,037 3,290 | 390 433 | 37,592 46,422 |
| **NET BENEFITS FROM GI ENHANCEMENTS** | | | | | | |
| Additional water diverted from sewers (1/yr) | 4,875,000 5,625,000 | 354,000 885,000 | 38,097,000 46,563,000 | 11,772,000 12,753,000 | 1,512,000 1,680,000 | 56,610,000 67,506,000 |
| Equivalent energy saving from avoiced water treatment (kWhr/yr) | 31,444 36,281 | 2,283 5,708 | 245,726 300,331 | 75,929 82,257 | 9,752 10,836 | 365,135 435,414 |
| Equivalent avoided $CO_2$ emissions saving (tCO 2/yr) | 17 19 | 1 3 | 132 161 | 41 44 | 5 6 | 196 234 |
| Tool 2.1 output: value of additional avoided $CO_2$ emissions saving (£/yr) | 826 1,033 | 65 162 | 6,994 8,548 | 2,161 2,341 | 278 308 | 10,324 12,392 |
| Tool 2.1 output: value of additional energy saving (£/yr) | 1,258 1,451 | 91 228 | 9,829 12,013 | 3,037 3,290 | 390 433 | 14,605 17,417 |

**TABLE 3:** WATER MANAGEMENT BENEFITS

# STRUCTURAL VALUES

## CTLA

In addition to estimating the environmental benefits provided by trees the i-Tree Eco model also provides a structural valuation. 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). It 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 in the Victoria BID (taking account of species suitability, depreciation and other economic considerations) should they become damaged or diseased for instance. The structural values for the ten most valuable tree species are shown in figure15.

The total value of all trees in the study area currently stands at £2,103,276. London plane is by far the most structurally valuable species of tree, on account of its size and population, followed by Norway maple and Tree of heaven. These three species of tree account for £1,815,430 (86%) of the total structural value of trees in Victoria.
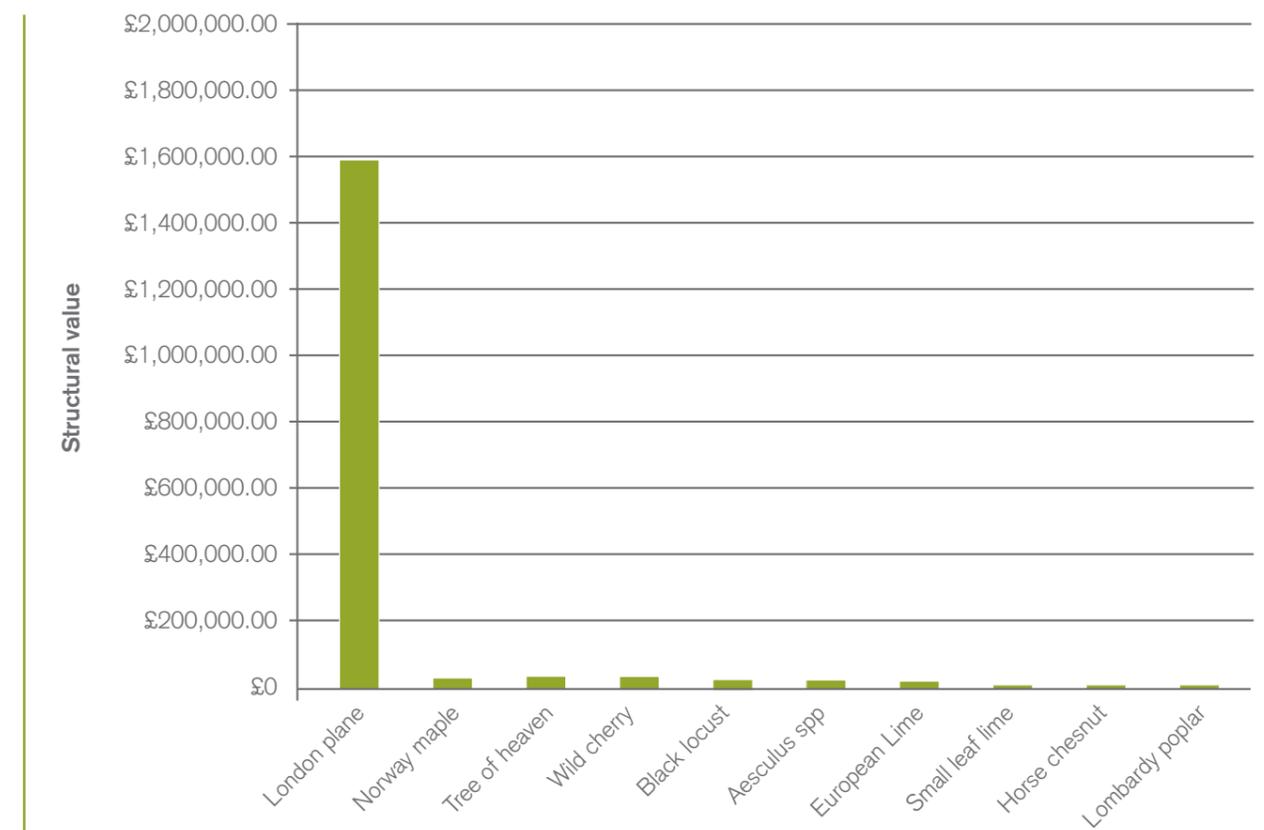


**FIG 15:** STRUCTURAL VALUES OF THE TOP TEN TREES

# CAVAT EVALUATION

The Capital Asset Valuation for Amenity Trees (CAVAT) approach was also used to provide an amenity valuation for the trees.

CAVAT has been developed in the UK, and provides a value for urban trees, based on an extrapolated and adjusted replacement cost, but in relation to the public amenity that they provide, rather than viewed as property (as per the CTLA approach used within i-Tree Eco). Particular differences to the CTLA trunk formula method include 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.

The requirement was to "retrofit" a CAVAT valuation for each of the trees originally surveyed. The pace of development in Victoria, even in this short period between studies meant that some trees originally recorded had been removed where new development was in progress, with yet more trees having been newly planted and therefore not recorded. Where some areas including privately owned trees had not been originally surveyed, or where access to some of the previously recorded privately owned trees could not be accomplished a CAVAT assessment was not made. In total 1,039 of the trees were evaluated.

The CAVAT full method was chosen to assess the trees. Although the 'quick method' is designed to be used in conjunction with street tree surveys as an aid to asset management of the tree stock as a whole (taking marginally less time to record), greater precision justified the use of the full method here.

To reach a CAVAT valuation the following are required:

- The current Unit Value Factor rating
- 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)
- Species and variety/ cultivar, if applicable, (to allow a judgement of relative amenity/ appropriateness in the location), and
- An assessment of Safe Life Expectancy.

Each tree was located using the original i-Tree survey, and the details recorded against the original number. That survey recorded DBH, which therefore was not re-measured. The CTI rating is constant across the borough, at 200%. In actuality therefore, the survey concentrated on accessibility, functionality, appropriateness and Safe Life Expectancy.

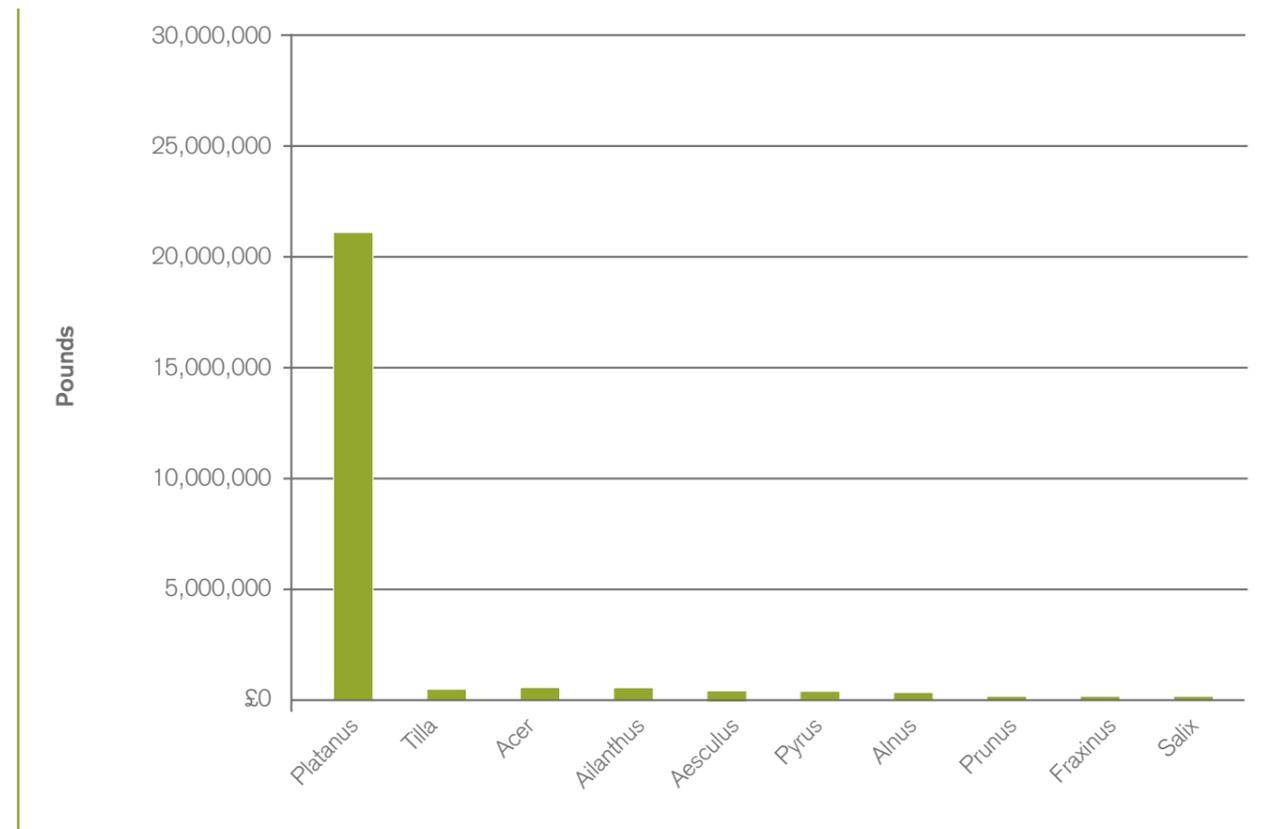| GENUS | VALUE (£) |
|---|---|
| PLATANUS | £22,263,088 |
| TILIA | £588,396 |
| ACER | £537,439 |
| AILANTHUS | £491,248 |
| AESCULUS | £400,439 |
| PYRUS | £303,664 |
| ALNUS | £295,748 |
| PRUNUS | £284,496 |
| FRAXINUS | £259,242 |
| SALIX | £258,110 |



**FIG 16:** CAVAT VALUES FOR THE TOP TEN TREES BY GENUS

Accessibility, while generally 100%, was judged to be reduced in some of the private squares and for trees on privately owned land where these did not immediately abut the street. Most trees were recorded as having well below 100% functionality, generally because limited space had restricted their full crown development.

The private squares in particular contained many attractive flowering trees, having correspondingly enhanced amenity ratings. Conversely the characteristic "honey-dew" drip of Limes, for example, an inappropriate attribute when found in streets and paved squares, led to a corresponding reduction in their value. (This sticky residue is notorious for dripping onto car paintwork and windscreens and is difficult to remove). London plane, overwhelmingly the most common large tree, was not penalised for the problems which can be experienced by some who have an adverse reaction to the irritating leaf hairs, but equally no extra value was added for the characteristic bark

effects on the basis that these are respectively too rare or not significant enough to affect their public value.

Safe Life Expectancy assessment was intended to be as realistic as possible, but based on existing circumstances, for example not allowing for possible impacts of global warming. For full details of the method refer to LTOA (2010).

Limitations on accuracy included the lack of access to private land, although most trees were capable of assessment from the street. The relative importance of the mature component of the tree population was clear, with these trees found on the wider streets, the parks, grounds of official buildings and the squares. Their high CAVAT values reflect their importance as major elements of the city-scape, the priority that needs to be placed in securing their continued health and in planting a wider and a variety of larger growing successor species for the future.

# POTENTIAL PEST IMPACTS

Various insects and diseases can potentially kill trees, consequently reducing their health and value, and therefore the 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 instance Asian longhorn beetle (detected in this country for the first time this year) and Massaria disease of plane (a recent phenomenon in the UK) have been selected to illustrate how the results from this survey can be used to estimate and tackle the potential pest impacts on the trees in the Victoria BID.

These pathogens have the potential to reduce the health or kill a number of trees that are present in Victoria BID. Figure 17 shows the pathogens, the potential percentage of population that could become infected and those which are immune.

The Asian longhorn beetle (ALB) is an insect that bores into and kills a wide range of hardwood species. This beetle could affect just under 40% (nearly 500) of the trees in Victoria BID. This beetle has only recently 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. Massaria disease was previously considered to be a weak parasite, and only capable of causing minor damage to trees. It is common in warmer Mediterranean climates and the southern United States. However, more recently it was found attacking mature trees in Germany, causing branch death and rapid decay.

As many of the affected trees have been street trees, the activity of this pathogen in causing branch dieback has resulted in a risk to public safety, and dead wood has to be removed before it becomes an unacceptable hazard (Tubby and Rose 2008).

Massaria disease has the potential to affect the Plane trees within the Victoria BID and these trees account for 29% of the total tree population.

Figure 15 shows the corresponding CTLA structural values which show the depreciated replacement cost for these trees.
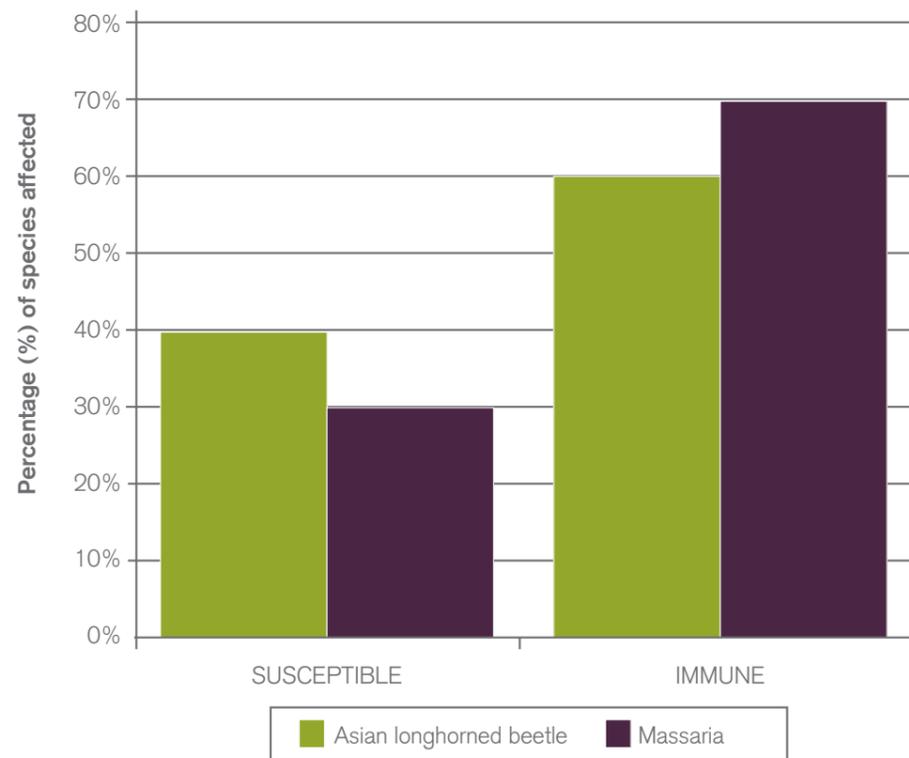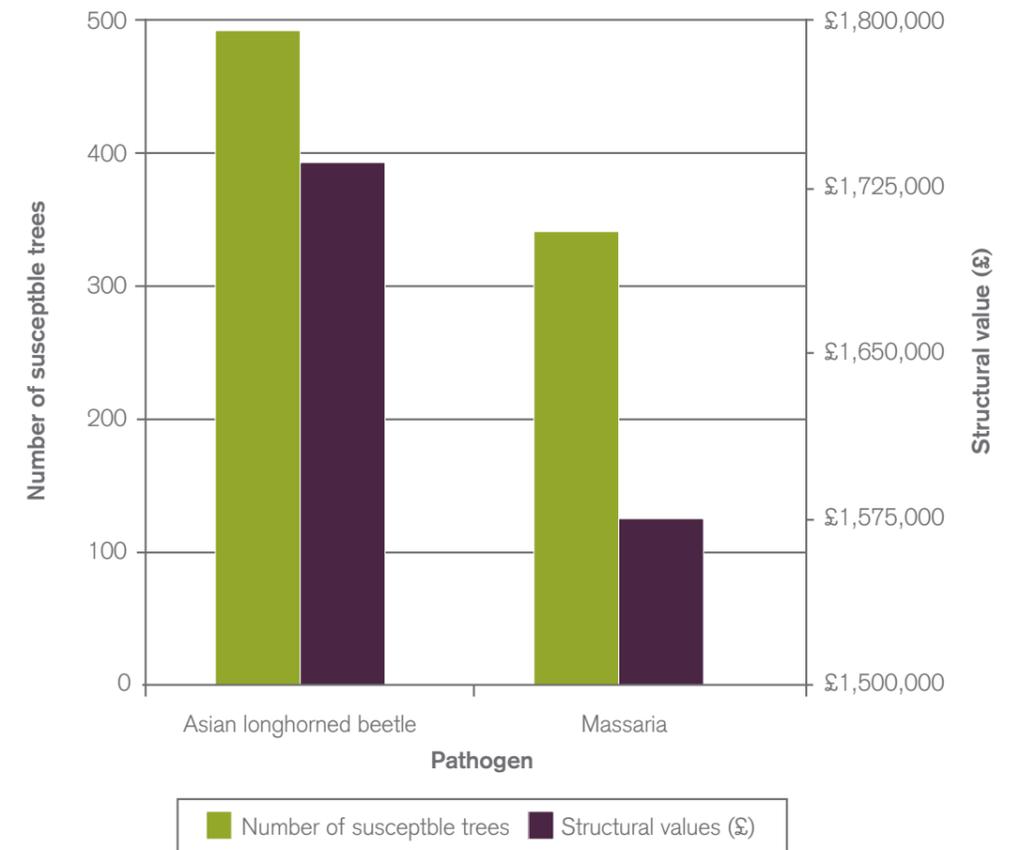


**FIG 18:** POTENTIAL PEST IMPACTS – NUMBER OF TREES SUSCEPTIBLE AND REPLACEMENT COSTS
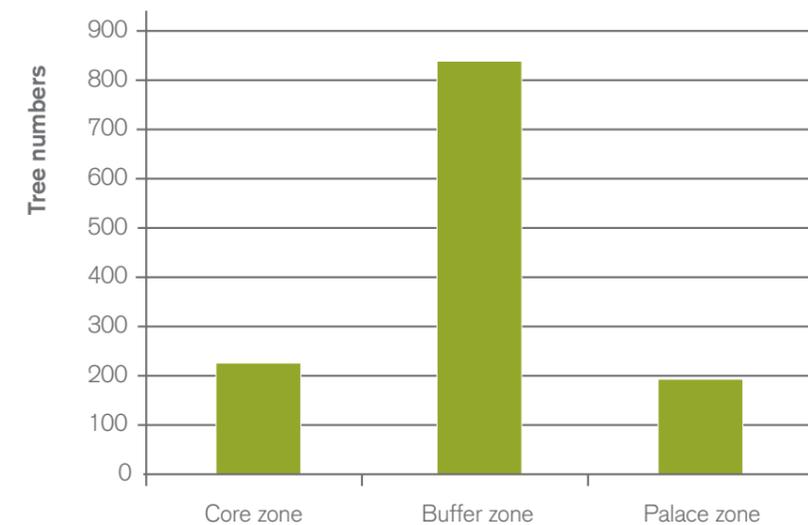


**FIG 17:** POTENTIAL PEST IMPACTS



**FIG 19:** TREE NUMBERS

# CORE ZONE AND BUFFER ZONE DATA

The study area is made up of both a Core and Buffer zone (see figure 1). As part of this study each individual tree location was recorded at time of survey, meaning that the data collected on these areas can be compared.

**Structure**
The majority of trees are found in the Buffer zone (figure 19). This is understandable as the surface area of the Core zone is dominated by the rail terminal and its ancillaries where there is little room in which to plant trees.
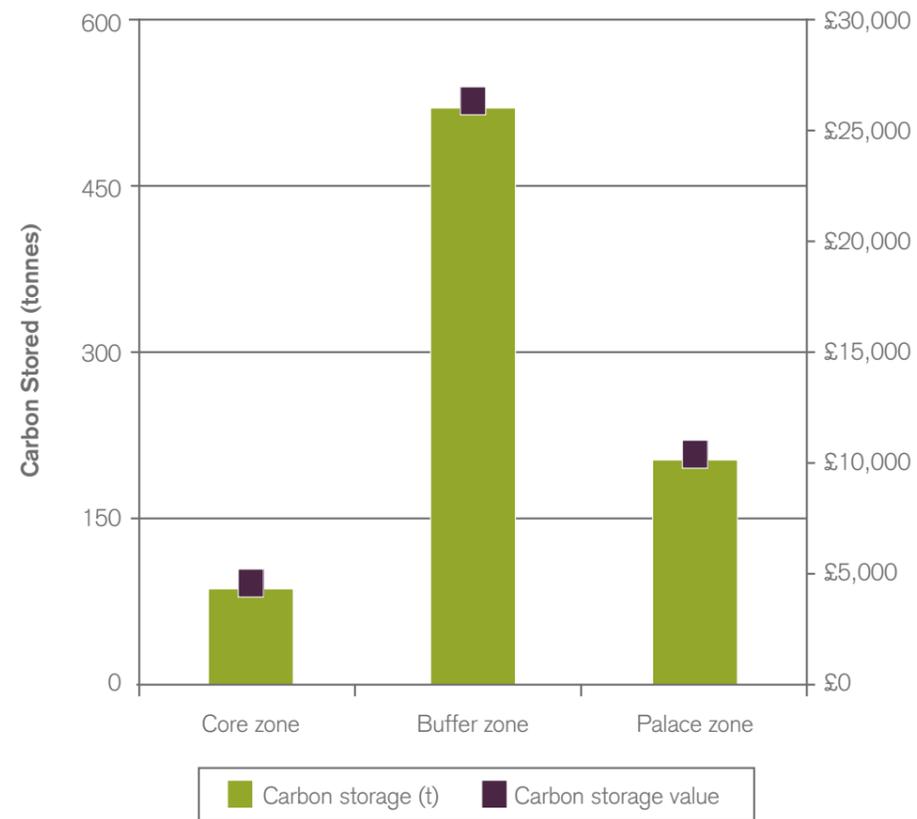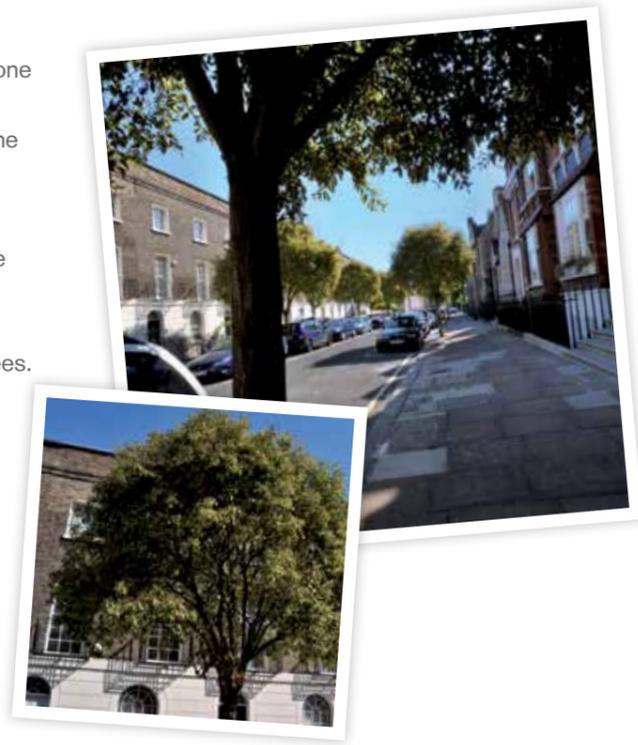






**FIG 20:** STRUCTURAL VALUE AND CARBON STORAGE BY ZONE

# DBH

Figure 21 gives a breakdown of average stem diameter, indicating that the largest and grandest trees are located within the Palace grounds, followed by those in the Buffer zone and finally the Core zone. Smaller trees are found in the Core zone and this is probably attributable to lack of available space, due to constraints such as impermeable surfaces of buildings and roads and underlying infrastructure, preventing trees from attaining a larger size. It also serves to illustrate the importance of the Buffer zone trees in supporting the reduced population (and benefits) in the Core zone.

It is therefore understandable then that both the structural value of the trees and the amount of carbon storage is also greater in the Buffer zone than the Core zone (see figure 20)).

Tree 420: A Chinese privet – Although these trees may store less carbon and filter less pollutants than their larger counterparts they are nonetheless vitally important for Victoria in providing diversity of species, shade and an amenity value.
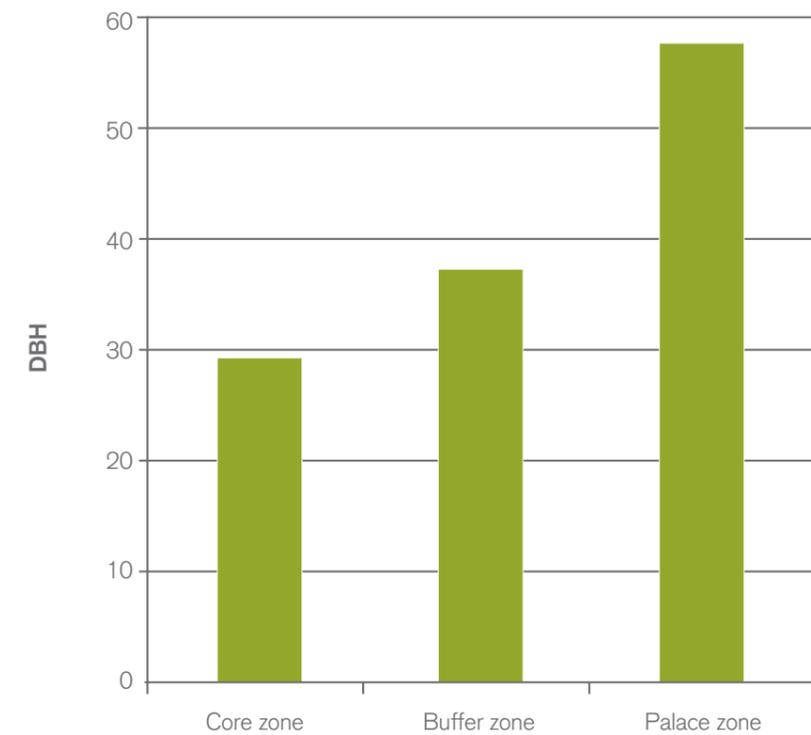
**FIG 21:** AVERAGE DBH

# CONCLUSION

Public and private trees in the Victoria BID provide valuable benefits. Realising the Mayor's target for increasing canopy cover together with the creation of additional green roofs and ground level green space would dramatically enhance the scale of ecosystem services the area enjoys.

The values presented in this study represent only a portion of the total value the urban forest and other green infrastructure assets provide because only a proportion of the total benefits have been evaluated. Trees confer many other benefits (de Groot et al 2010). Therefore, the values presented in this report should be seen as representing only a part of a bigger picture.

These conclusions highlight some key recommendations in order to ensure that benefits currently arising from the BID's green infrastructure are sustained and future green investments fulfill their potential for generating returns.

**Conduct succession planting for London planes**
The local tree resource is characterised by a good diversity of species, which makes it more resilient to pressures such as pests and diseases or climate change. However, most of the canopy area and therefore most of the benefits arising from the Victoria BID's treescape are provided by London planes. Many of these trees are mature specimens, as has already been highlighted in previous studies (Kelly 2012). Provision should be made to ensure that adequate succession planting is carried out in order to maintain benefits at the current levels.

**Target private trees owners for awareness raising and best practice on tree management**
Many of the BID's trees are in the private realm and in the buffer area. Therefore, a reduction in privately owned trees will reduce this benefit. Strategies and policies that will serve to conserve this important resource (through education and community engagement for example) would be one way to address this.

**Focus on large canopy trees both for planting and maintenance**
The amount of healthy leaf area equates directly to the provision of benefits (or ecosystem services). Canopy cover can be increased through new tree plantings. However, the most effective strategy for increasing average tree size and tree canopy is to preserve and manage the existing trees within the BID so that a good proportion can grow to maturity.

Where new trees are planted the Westminster Trees and the Public Realm SPD (Westminster City Council 2009) recommends using the tree species with the largest canopy a site can accommodate. Ensuring this is well-enforced in the future will be key to maintaining tree benefits at their current level.

**Engage with Thames Water to ensure the benefits from proposed green investments can more directly reach BID members**
Trees currently make a positive contribution to the management of storm water in Victoria. The proposed investment to increase canopy cover, create new ground level green spaces and dramatically extend the area of green roofs and will significantly alleviate the local drainage system.

This will unarguably result in public benefits, by contributing to reducing the prevalence of flooding events which regularly damage and interfere with the local infrastructure. It will also reduce the amount of water that will need to be treated by the local water company, Thames Water, thus offering real savings. All efforts should be made to ensure local owners and occupiers in Victoria who, as part of their water bill, pay for the drainage of the area get access to their share of this saving.

Contrary to other water companies in the country (such as United Utilities in the north west region), Thames Water grant a rebate to its customers on drainage fees based on pipe diameter rather than based on volume reduction. This doesn't provide a strong incentive for green approaches such as those envisaged for Victoria. Direct engagement with Thames Water on this issue could result in an innovative pilot – offering a model that could be rolled out to other parts of London.

# APPENDIX 1

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

For the UK however, the appropriate way to monetise the carbon sequestration benefit is to multiply the tonnes of carbon stored by the non-traded price of carbon, because this carbon is not part of the EU carbon trading scheme. The non-traded price is not based on the cost to society of emitting the carbon, but is based on the cost of not emitting the tonne of carbon elsewhere in the UK in order to remain compliant with the Climate Change Act (DECC 2009).

This approach gives higher values to carbon than the approach used in the United States, reflecting the UK Government's response to the latest science, which shows that deep cuts in emissions are required to avoid the worst effects of climate change (DECC 2009).

Official pollution values for the UK are based on the estimated social cost of the pollutant in terms of impact upon human health, damage to buildings and crops. Values were taken from the Interdepartmental Group on Costs and Benefits (IGCB) based on (DEFRA, 2007). They are a conservative estimate because they do not include damage to ecosystems; SO2 negatively impacts trees and freshwater and NOx contributes to acidification and eutrophication (DEFRA, 2007). For PM10s, which are the largest element of the air pollution benefit, a range of economic values is available depending on how urban (hence densely populated) the area under consideration is (IGCB 2011).

For both carbon and air pollution removal, the assumption has been made that the benefit to society from a tonne of gas removed is the same as the cost to society of a tonne of the same gas emitted (Sunderland et al 2011).

# APPENDIX 2

**UFORE Model and Field Measurements**

UFORE is designed to use standardised field data from randomly located plots and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, 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 (<10 microns).
- Total carbon stored and net carbon annually sequestered by the urban forest.
- 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 pathogens and infestations for example; Asian long-horned beetle, gypsy moth, and Dutch elm disease.

Typically, all field data is collected during the leaf-on season to properly assess tree canopies. Within each plot, typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005).

Not all of the US functions are suitable for the UK and the methodology was also adapted to suit UK conditions (Rogers et al 2011).

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 (Nowak 1994). 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.

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 (Baldocchi 1987, Baldocchi et al 1988, Bidwell and Fraser 1972). 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 (Lovett 1994, Zinke 1967) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent re-suspension rate of particles back to the atmosphere (McPherson and Simpson 1999).

If appropriate field data were collected, seasonal effects of trees on residential building energy use was calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height and tree condition data.

Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers (Hollis 2007), which uses tree species, diameter, condition and location information (Nowak et al 2002).

# APPENDIX 3

**General Recommendations for Air Quality Improvement**

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (Nowak 1995):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (Nowak and Dwyer 2007). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include (Nowak 2000):

| STRATEGY RESULT | RESULT |
| --- | --- |
| INCREASE THE NUMBER OF HEALTHY TREES | INCREASE POLLUTION REMOVAL |
| SUSTAIN EXISTING TREE COVER | MAINTAIN POLLUTION REMOVAL LEVELS |
| MAXIMIZE USE OF LOW VOC-EMITTING TREES | REDUCES OZONE AND CARBON MONOXIDE FORMATION |
| SUSTAIN LARGE, HEALTHY TREES | LARGE TREES HAVE GREATEST PER-TREE EFFECTS |
| USE LONG-LIVED TREES | REDUCE LONG-TERM POLLUTANT EMISSIONS FROM PLANTING AND REMOVAL |
| USE LOW MAINTENANCE TREES | REDUCE POLLUTANTS EMISSIONS FROM MAINTENANCE ACTIVITIES |
| REDUCE FOSSIL FUEL USE IN MAINTAINING VEGETATION | REDUCE POLLUTANT EMISSIONS |
| PLANT TREES IN ENERGY CONSERVING LOCATIONS | REDUCE POLLUTANT EMISSIONS FROM POWER PLANTS |
| PLANT TREES TO SHADE PARKED CARS | REDUCE VEHICULAR VOC EMISSIONS |
| SUPPLY AMPLE WATER TO VEGETATION | ENHANCE POLLUTION REMOVAL AND TEMPERATURE REDUCTION |
| PLANT TREES IN POLLUTED OR HEAVILY POPULATED AREAS | MAXIMIZES TREE AIR QUALITY BENEFITS |
| AVOID POLLUTANT-SENSITIVE SPECIES | IMPROVE TREE HEALTH |
| UTILIZE EVERGREEN TREES FOR PARTICULATE MATTER | YEAR-ROUND REMOVAL OF PARTICULATES |

# APPENDIX 4

**Background on the Green Infrastructure Valuation Toolkit.**

The project was initiated in December 2008 by a consortium of organisations convened by Natural Economy Northwest, managed by Tees Valley Unlimited and involving The Northern Way, Natural England, Design for London and the Commission for Architecture and the Built Environment (CABE), with support from the Department for Environment, Food and Rural Affairs (Defra) and five economic development agencies: One North East, Yorkshire Forward Advantage West Midlands, the Northwest Development Agency, and the London Development Agency. The toolkit was released as a prototype in February 2011 under a Creative Commons license and can be accessed for free at www.bit.ly/givaluationtoolkit. It has been widely tested in projects in Merseyside, Wales, Swindon, London and France.

By offering a simple means to articulate and estimate returns on investment in green assets – whether those benefits directly contribute to a local economy, or provide wider non-economic returns for society and the environment – the toolkit provides a shared language for planners, investors, and environmentalists to better collaborate and make decisions.

The benefit estimation framework the Green Infrastructure Valuation Toolkit relies on includes 11 categories:

1. Labour productivity
2. Tourism
3. Recreation and Leisure
4. Biodiversity
5. Land products
6. Climate change adaptation and mitigation
7. Water management
8. Quality of place and communities
9. Health and wellbeing
10. Property values
11. Investment

This framework is open to further refinement, for example, some areas of benefits such as transport are yet to be incorporated, but it offers a good starting point that is easily understood by a wide audience.

A set of tools has been developed within each of the 11 categories to look at how the range of green infrastructure benefits deriving from a landscape asset or investment can be valued:

In monetary terms; applying economic valuation techniques where possible to scope both potential economic impacts (i.e.: those directly affecting GVA) and wider economics benefits (i.e.: value of non-market environmental goods and services).

Quantitatively; for example with reference to number of jobs or visitors, amount of air pollution removed, temperature impact, etc.

Qualitatively; referencing case studies or important research where there appears to be a link between green infrastructure and economic, societal or environmental benefits, but where the scientific basis for quantification and/or monetisation is not yet sufficiently robust.

To ensure results are easy to interpret and are easy to compare, monetised findings are expressed in terms of Net Present Value (NPV). This captures the sum of the present and discounted future flows of net benefits of a particular asset over its entire lifetime. A discount rate, following HM Treasury current Green Book guidance is used to reduce future benefits and costs to their present time equivalent.

# APPENDIX 5

**Number of Trees and their characteristics (The most common species appears first)**

| SPECIES NAME | GENUS | SPECIES | SPECIES QUANTITY | CARBON STORAGE (t) | GROSS CARBON SEQ (t/yr) | LEAF AREA (m2) | TREE VALUE (£) USEC |
|---|---|---|---|---|---|---|---|
| London plane | Platanus | x hispanica | 360 | 662.02 | 10.80 | 252030.76 | £1,590,096.83 |
| Callery pear | Pyrus | calleryana | 84 | 3.56 | 0.45 | 3960.1 | £7,780.55 |
| Wild cherry | Prunus | avium | 62 | 13.54 | 0.72 | 9865.27 | £34,084.39 |
| Common lime | Tillia | europaea | 48 | 5.05 | 0.28 | 6367.31 | £20,952.70 |
| Small leaf lime | Tilia | cordata | 38 | 4.49 | 0.21 | 4970.01 | £19,779.70 |
| Holly | Ilex | aqufolium | 32 | 2.37 | 0.17 | 1455.36 | £6,231.52 |
| Pillar apple | Malus | tschonoskii | 27 | 0.93 | 0.14 | 2665.04 | £1,615.39 |
| Sorbus spp. | Sorbus | spp. | 27 | 2.72 | 0.21 | 2586.21 | £6,826.86 |
| Italian alder | Alnus | cordata | 26 | 5.52 | 0.30 | 3706.73 | £14,019.02 |
| Manna ash | Fraxinus | ornus | 22 | 2.79 | 0.18 | 2644.1 | £8,212.84 |
| Bird cherry | Prunus | padus | 20 | 3.12 | 0.17 | 2108.3 | £7,333.73 |
| Black locust | Robinia | pseudocacia | 20 | 1.67 | 0.17 | 2874.1 | £24,089.94 |
| Silver birch | Betula | pendula | 18 | 0.73 | 0.08 | 2451.87 | £1,758.86 |
| Indian paper birch | Betula | utilis | 18 | 1.50 | 0.14 | 2095.27 | £2,651.24 |
| Hornbeam | Carpinus | betulus | 16 | 2.07 | 0.13 | 1819.19 | £6,162.00 |
| Norway maple | Acer | platanoides | 16 | 12.19 | 0.30 | 7267.51 | £36,722.99 |
| Aesculus spp. | Aesculus | spp. | 15 | 8.36 | 0.26 | 8166.71 | £21,725.00 |
| Japanese maple | Acer | palmatum | 15 | 4.14 | 0.20 | 3657.52 | £11,786.80 |
| Ceanothus spp. | Ceanothus | spp. | 14 | 0.74 | 0.06 | 541.37 | £1,540.18 |
| Lawson cypress | Chamaecyparis | lawsoniana | 14 | 1.64 | 0.07 | 1331.43 | £6,689.72 |
| Cherry plum | Prunus | cerasifera | 13 | 0.62 | 0.06 | 721.13 | £1,007.41 |
| Maidenhair Tree | Ginkgo | biloba | 12 | 1.25 | 0.08 | 1697.13 | £3,071.52 |
| Chinese privet | Ligustrum | sinense | 11 | 0.58 | 0.07 | 998.64 | £806.43 |
| Sweet gum | Liquidambar | styraciflua | 11 | 0.59 | 0.03 | 579.62 | £1,935.18 |
| Hawthorn | Crataegus | monogyana | 11 | 1.09 | 0.09 | 761.35 | £2,643.66 |
| Tree of heaven | Ailanthus | altissima | 10 | 16.70 | 0.35 | 4148.93 | £35,414.75 |
| Kanzan cherry | Prunus | Kanzan | 9 | 0.56 | 0.05 | 438.17 | £1,152.77 |
| Pin oak | Quercus | pulusris | 9 | 0.45 | 0.05 | 283.44 | £1,088.30 |
| Malus spp. | Malus | spp. | 8 | 0.57 | 0.05 | 445.93 | £1,435.27 |
| Indian Bean Tree | Catalpa | bignonioides | 8 | 6.23 | 0.10 | 726.24 | £9,015.48 |
| Common lilac | Syringa | vulgaris | 7 | 0.50 | 0.03 | 327.58 | £1,479.51 |
| Field maple | Acer | campestre | 7 | 0.30 | 0.04 | 730.34 | £569.43 |
| Leyland cypress | x Cupressocyparis | leylandii | 7 | 1.01 | 0.03 | 594.25 | £3,722.48 |
| Ash | Fraxinus | excelsior | 6 | 1.75 | 0.07 | 1133.61 | £6,707.42 |

| SPECIES NAME | GENUS | SPECIES | SPECIES QUANTITY | CARBON STORAGE (t) | GROSS CARBON SEQ (t/yr) | LEAF AREA (m2) | TREE VALUE (£) USEC |
|---|---|---|---|---|---|---|---|
| Black mulberry | Morus | nigra | 6 | 1.49 | 0.06 | 1369.86 | £3,984.13 |
| Olive | Olea | europaea | 6 | 0.24 | 0.03 | 200.02 | £427.86 |
| Beech | Fagus | sylvatica | 5 | 6.04 | 0.13 | 2956.62 | £14,630.80 |
| Lombardy poplar | Populus | nigra 'Italica' | 5 | 4.38 | 0.11 | 64.02 | £15,394.89 |
| Prunus spp. | Prunus | spp. | 5 | 1.42 | 0.06 | 640.25 | £3,030.44 |
| Portugal laurel | Prunus | lusitanica | 5 | 0.59 | 0.05 | 348.2 | £1,273.48 |
| Rowan | Sorbus | aucuparia | 5 | 0.12 | 0.01 | 221.33 | £288.19 |
| Sycamore | Acer | pseudoplatanus | 5 | 1.95 | 0.07 | 1024.08 | £6,116.50 |
| Elder | Sambucus | nigra | 4 | 0.91 | 0.04 | 246.53 | £2,823.14 |
| Common Yew | Taxus | baccata | 4 | 0.58 | 0.02 | 347.6 | £4,001.19 |
| Horse chestnut | Aesculus | hippocastanum | 4 | 10.75 | 0.18 | 4290.19 | £17,168.91 |
| Magnolia spp | magnolia | spp. | 4 | 0.63 | 0.03 | 336.38 | £1,818.90 |
| Acer spp. | Acer | spp. | 4 | 0.51 | 0.02 | 401.07 | £1,289.28 |
| Silver maple | Acer | saccharinum | 4 | 2.76 | 0.06 | 1870.42 | £10,213.75 |
| Stag's-horn Sumach | Rhus | typhina | 4 | 0.12 | 0.02 | 74.94 | £424.07 |
| Sydney golden wattle | Acacia | longifolia | 4 | 0.10 | 0.01 | 131.04 | £212.35 |
| Turkish hazel | Corylus | colurna | 4 | 0.28 | 0.03 | 420.83 | £631.37 |
| Weeping willow | Salix | x sepulcralis 'Chrysucoma' | 4 | 3.77 | 0.09 | 1377.17 | £10,843.86 |
| Common pear | Pyrus | communis | 3 | 0.51 | 0.03 | 308.68 | £1,471.93 |
| Cut leaf Lime | Tilia | x mongolica | 3 | 0.24 | 0.02 | 577.7 | £996.66 |
| Kentucky coffee tree | Gymnocladus | dioica | 3 | 0.58 | 0.03 | 549.85 | £1,480.14 |
| Mimosa | Acacia | dealbata | 3 | 0.05 | 0.01 | 88.39 | £128.93 |
| Smalltoothed willow | Salix | spp. | 3 | 4.92 | 0.09 | 1312.57 | £12,650.11 |
| Strawberry tree | Arbutus | unedo | 3 | 0.39 | 0.02 | 138.69 | £1,137.60 |
| Striped maple | Acer | pensylvanicum | 3 | 0.23 | 0.02 | 281.18 | £414.59 |
| Wych elm | Ulmus | glabra | 3 | 0.32 | 0.02 | 313.08 | £542.89 |
| Bay laurel | Laurus | nobilis | 2 | 0.23 | 0.01 | 66.98 | £683.82 |
| Black cherry | Prunus | serotina | 2 | 0.43 | 0.03 | 77.54 | £954.32 |
| Black poplar | Populus | nigra | 2 | 3.97 | 0.07 | 1076.11 | £11,315.33 |
| Camellia | Camellia | japonica | 2 | 0.04 | 0.00 | 85.79 | £102.38 |
| Caucasian Wingnut | Pterocarya | fraxinifolia | 2 | 1.33 | 0.04 | 599.46 | £3,553.74 |
| Cherry laurel | Prunus | laurocerasus | 2 | 0.32 | 0.02 | 173.6 | £736.91 |
| Common apple | Malus | domestica | 2 | 0.10 | 0.01 | 114.81 | £253.43 |
| Cut leaved birch | Betula | pendula 'Dalecarlica' | 2 | 0.03 | 0.01 | 22.56 | £94.80 |
| Cypress spp | Cupressus | spp. | 2 | 0.47 | 0.01 | 440.21 | £1,750.64 |
| Deodar cedar | Cedrus | deodara | 2 | 1.82 | 0.03 | 2396.52 | £8,734.87 |
| European medlar | Morus | nigra | 2 | 0.74 | 0.02 | 326.31 | £1,493.42 |
| Korean maple | Acer | pseudosieboldianum | 2 | 0.21 | 0.02 | 528.42 | £427.23 |

| SPECIES NAME | GENUS | SPECIES | SPECIES QUANTITY | CARBON STORAGE (t) | GROSS CARBON SEQ (t/yr) | LEAF AREA (m2) | TREE VALUE (£) USEC |
|---|---|---|---|---|---|---|---|
| Largeleaf lime | Tilia | platyphyllos | 2 | 0.67 | 0.02 | 902.95 | £3,168.85 |
| Paper birch | Betula | papyrifera | 2 | 0.98 | 0.04 | 754.21 | £2,361.78 |
| Red horse chestnut | Aesculus | x carneac | 2 | 4.91 | 0.08 | 871.4 | £12,560.37 |
| Red oak | Quercus | rubra | 2 | 0.18 | 0.01 | 240.92 | £496.75 |
| Snowy mespil | Amelanchier | canadensis | 2 | 0.32 | 0.02 | 129.96 | £980.86 |
| Tulip tree | Liriodendron | tulipifera | 2 | 0.51 | 0.02 | 416.4 | £1,526.28 |
| Variegated sycamore | Acer | pseudoplatanus | 2 | 0.05 | 0.01 | 312.3 | £113.76 |
| White poplar | Populus | alba | 2 | 5.99 | 0.09 | 178.75 | £14,565.70 |
| Balsam poplar | Populus | balsamifera | 1 | 0.02 | 0.00 | 14.22 | £59.41 |
| Basket willow | Salix | viminalis | 1 | 0.05 | 0.00 | 39.42 | £99.22 |
| Bishop pine | Pinus | muricata | 1 | 0.08 | 0.00 | 43.64 | £449.35 |
| Black oak | Quercus | nigra | 1 | 0.63 | 0.02 | 31.31 | £1,688.70 |
| Blackbrush acacia | Acacia | rigidula | 1 | 0.09 | 0.01 | 62.13 | £203.50 |
| Blackthorn | Prunus | spinosa | 1 | 0.14 | 0.01 | 70.53 | £310.94 |
| Blierana plum | Prunus | x blieriana | 1 | 0.01 | 0.00 | 23.32 | £32.86 |
| Buckbrush | Ceanothus | cuneatus | 1 | 0.03 | 0.00 | 70.5 | £45.50 |
| California flannelbush | Fremontodendron | californicum | 1 | 0.01 | 0.00 | 12.09 | £39.18 |
| Chinese catalpa | Catalpa | ovata | 1 | 0.04 | 0.00 | 85.02 | £65.10 |
| Chinese magnolia | Magnolia | denudata | 1 | 0.19 | 0.01 | 126.38 | £550.47 |
| Cider gum eucalyptus | Eucalyptus | gunnii | 1 | 0.05 | 0.00 | 9.75 | £65.73 |
| Common box | Buxus | sempervirens | 1 | 0.02 | 0.00 | 28.8 | £41.71 |
| Common fig | Ficus | carica | 1 | 0.01 | 0.00 | 18.36 | £41.71 |
| Nootka Cypress | Xanthocyparis | nootkatensis | 1 | 0.08 | 0.00 | 35.19 | £307.78 |
| Dawn redwood | Metasequoia | glyptostroboides | 1 | 0.20 | 0.01 | 250.31 | £1,044.06 |
| Dombey's Beech | Nothofagus | dombeyi | 1 | 0.08 | 0.01 | 92.56 | £142.83 |
| English oak | Quercus | robur | 1 | 0.41 | 0.02 | 255.24 | £1,159.09 |
| European aspen | Populus | tremula | 1 | 0.42 | 0.01 | 206.23 | £1,607.81 |
| European larch | Larix | decidua | 1 | 0.05 | 0.00 | 117.74 | £147.26 |
| Feltleaf ceanthous | Ceanothus | arboreus | 1 | 0.09 | 0.01 | 61.34 | £208.56 |
| Fullmoon maple | Acer | japonicum | 1 | 0.01 | 0.00 | 107.1 | £47.40 |
| Golden chain tree | Laburnum | anagyroides | 1 | 0.13 | 0.00 | 15.98 | £103.02 |
| Goldenrain tree | Koelreuteria | paniculata | 1 | 0.05 | 0.00 | 92.65 | £87.22 |
| Grey alder | Alnus | incana | 1 | 0.28 | 0.01 | 181.99 | £832.98 |
| Harlequin glorybower | Clerodendrum | trichotomum | 1 | 0.02 | 0.00 | 92.38 | £41.71 |
| Hazel | Corylus | avellana | 1 | 0.01 | 0.00 | 30.88 | £47.40 |
| Higan cherry | Prunus | subhirtelle | 1 | 0.05 | 0.01 | 79.66 | £75.21 |
| Honeylocust | Gleditsia | triacanthos | 1 | 0.07 | 0.01 | 75.39 | £133.98 |
| Hybrid black popular | Populus | X canadensis | 1 | 1.36 | 0.03 | 680.35 | £4,530.18 |

| SPECIES NAME | GENUS | SPECIES | SPECIES QUANTITY | CARBON STORAGE (t) | GROSS CARBON SEQ (t/yr) | LEAF AREA (m2) | TREE VALUE (£) USEC |
|---|---|---|---|---|---|---|---|
| Japanese persimmon | Kaki | Persimmon | 1 | 0.09 | 0.01 | 135.81 | £180.75 |
| Japanese viburnum | Viburnum | japonicum | 1 | 0.41 | 0.01 | 47.48 | £1,301.92 |
| Japanese zelkova | Zelkova | serrata | 1 | 0.13 | 0.01 | 119.82 | £326.74 |
| Judas tree | Cercis | siliquastrum | 1 | 0.04 | 0.00 | 80.64 | £68.89 |
| Lily of the valley tree | Clethra | arborea | 1 | 0.05 | 0.00 | 38.45 | £87.22 |
| mahonia spp | Mahonia | spp. | 1 | 0.04 | 0.01 | 26.01 | £48.66 |
| Manchurian Cherry | Prunus | maackii | 1 | 0.04 | 0.00 | 0 | £0.00 |
| Narrowleaf cottonwood | Populus | angustifolia | 1 | 0.16 | 0.01 | 71.47 | £753.98 |
| Oak spp | Quercus | spp. | 1 | 0.06 | 0.01 | 20.93 | £92.27 |
| Ovens wattle | Acacia | pravissima | 1 | 0.04 | 0.00 | 70.5 | £59.41 |
| Pacific dogwood | Cornus | nuttallii | 1 | 0.04 | 0.00 | 1357.83 | £51.82 |
| Parathesis spp | Parathesis | spp. | 1 | 0.06 | 0.01 | 25.14 | £80.90 |
| Pear spp | Pyrus | spp. | 1 | 0.09 | 0.01 | 19.29 | £228.15 |
| Quince | Cydonia | oblonga | 1 | 0.01 | 0.00 | 14.83 | £31.60 |
| Red maple | Acer | rubra | 1 | 0.14 | 0.01 | 101.14 | £355.18 |
| Royal paulownia | Paulownia | tomentosa | 1 | 0.86 | 0.03 | 297.24 | £2,171.55 |
| Shiny cotoneaster | Cotoneaster | lucidus | 1 | 0.10 | 0.01 | 62.99 | £219.94 |
| Siberian crabapple | Malus | baccata | 1 | 0.13 | 0.01 | 94.06 | £355.18 |
| Silver Kohuhu | Pittosporum | tenuifolium | 1 | 0.05 | 0.01 | 64.7 | £87.22 |
| Acacia spp. | Acacia | spp. | 1 | 0.01 | 0.00 | 15.99 | £41.71 |
| Guelder Rose | Viburnum | opulus | 1 | 0.04 | 0.00 | 61.97 | £68.89 |
| Spindle | Euonymus | europaeus | 1 | 0.02 | 0.00 | 10.21 | £44.24 |
| Star magnolia | Magnolia | stellata | 1 | 0.05 | 0.01 | 28.82 | £96.06 |
| Sweet almond | Prunus | dulcis | 1 | 0.05 | 0.00 | 43.92 | £51.82 |
| Himalayan Tree cotoneaster | Cotoneaster | frigidus | 1 | 0.06 | 0.00 | 60.07 | £73.31 |
| Turkey oak | Quercus | cerris | 1 | 0.74 | 0.03 | 224.24 | £1,941.50 |
| White ash | Fraxinus | alba | 1 | 0.07 | 0.01 | 31.31 | £110.60 |
| White mulberry | Morus | alba | 1 | 0.13 | 0.01 | 147.44 | £326.74 |

# REFERENCES

Asadian Y. and Weiler M. (2009), A New Approach in Measuring Rainfall Interception by Urban Trees in Coastal British Columbia, Water Quality Research Journal of Canada, Volume 44, No. 1, 16-25

Baldocchi, D (1988). A multi-layer model for estimating sulfur dioxide deposition to a deciduous oak forest canopy. Atmospheric Environment. 22: 869-884.

Baldocchi, D.D.; Hicks, B.B.; Camara, P (1987). A canopy stomatal resistance model for gaseous deposition to vegetated surfaces. Atmospheric Environment. 21: 91-101.

Bidwell, R.G.S.; Fraser, D.E (1972). Carbon monoxide uptake and metabolism by leaves. Canadian Journal of Botany. 50: 1435-1439.

Britt, C., Johnston, M (2008). Trees in Towns II - A new survey of urban trees in England and their condition and management. Department for Communities and Local Government, London.

Calder, I. R., Reid, I., Nisbet, T. and Green, J. C (2003). Impact of lowland forests in England on water resources – application of the HYLUC model. Water Resources Research 39, 1319–1328

DECC 2009. Carbon Appraisal in UK Policy Appraisal: A revised Approach - A brief guide to the new carbon values and their use in economic appraisal.

DEFRA 2007. The air quality strategy for England, Scotland, Wales and Northern Ireland. DEFRA. London.

Gill, S., Handley, A., Ennos, A., Paulett, S (2007). Adapting cities for climate change: the role of green infrastructure. Built Environment 33 (1), 115-133.

Grove, J.M, Oneil-Dunne, J., Pelletier, K., Nowak D., and Walton, J (2006). A report on New York City's present and possible urban tree canopy. U.S. Department of Agriculture, Forest Service. Syracuse, NY.

Hollis, A (2007). Depreciated replacement cost in amenity tree valuation. UKI- RPAC guidance note 1.

Hulme, M et al (2002). Climate change scenarios for the United Kingdom: UKCIP02 Scientific Report. Norwich: Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia.

IGCB. Air quality damage costs per tonne, 2011 prices [Online]. Available at: http://www.defra.gov.uk/environment/quality/air/air-quality/economic/damage/ [Accessed May 20th 2011].

Lovasi, G. S. et al (2008). Children living in areas with more street trees have lower prevalence of asthma. Journal of Epidemiology and Community Health 62(7):647-9).

Lovett, G.M (1994). Atmospheric deposition of nutrients and pollutants in North America: an ecological perspective. Ecological Applications. 4: 629-650.

LTOA (2010). [Online]. Available at: http://www.ltoa.org.uk/resources/cavat [Accessed 31/5/12].

McPherson, E.G. and J. R. Simpson (1999). Carbon dioxide reduction through urban forestry: guidelines for professional and volunteer tree planters. Gen. Tech. Rep. PSW- 171. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research station 237 p.

Peachey, C.J., et al (2009). Deposition and solubility of airborne metals to four plant species grown at varying distances from two heavily trafficked roads in London. Environmental Pollution 157: 2291–2299.

Nowak, D.J (1994). Atmospheric carbon dioxide reduction by Chicago's urban forest. In: McPherson, E.G.; Nowak, D.J.; Rowntree, R.A., eds. Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project. Gen. Tech. Rep. NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 83-94.

Nowak, D.J (1995). Trees pollute? A "TREE" explains it all. In: Proceedings of the 7th National Urban Forestry Conference. Washington, DC: American Forests. Pp. 28-30.

Nowak, D.J (2000). The interactions between urban forests and global climate change. In: Abdollahi, K.K., Z.H. Ning, and A. Appeaning (Eds). Global Climate Change and the Urban Forest. Baton Rouge: GCRCC and Franklin Press. Pp. 31-44.

Nowak, D (2006). Institutionalizing urban forestry as a "biotechnology" to improve environmental quality. Urban Forestry and Urban Greening 5, 93-100.

Nowak, D., Civerolo, K., Rao, S., Sistla, G,. Luley, C., Crane, D (2000). A modeling study of the impact of urban trees on ozone. Atmospheric Environment 34, 1601-1613.

Nowak, D.J., and D.E. Crane (2000). The Urban Forest Effects (UFORE) Model: quantifying urban forest structure and functions. In: Hansen, M. and T. Burk (Eds.) Integrated Tools for Natural Resources Inventories in the 21st Century. Proc. Of the IUFRO Conference. USDA Forest Service General Technical Report NC-212. North Central Research Station, St. Paul, MN. pp. 714-720.

Nowak, D.J.; Crane, D.E.; Stevens, J.C.; Ibarra, M (2002). Brooklyn's Urban Forest. Gen. Tech. Rep. NE-290. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 107 p. Council of Tree and Landscape Appraisers guidelines. For more information, see Nowak, D.J., D.E. Crane, and J.F. Dwyer. 2002. Compensatory value of urban trees in the United States. J. Arboric. 28(4): 194-199.

Nowak, D.J.; Crane, D.E.; Stevens, J.C.; Hoehn, R.E (2005). The urban forest effects (UFORE) model: field data collection manual. V1b. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station, 34 p.

Nowak,D., Crane, D., Stevens, J (2006). Air pollution removal by urban trees and shrubs in the United States. Urban Forestry and Urban Greening 4, 115-123.

Nowak, D.J. and J.F. Dwyer (2007). Understanding the benefits and costs of urban forest ecosystems. In: Kuser, J. (ed.) Urban and Community Forestry in the Northeast. New York: Springer. Pp. 25-46.

Rodbell, P, Marshall, S (2009). Urban tree canopy as a contibutor to community resilience. In, proceedings of the XIII World Forestry Congress (2009), Buenos Aires, Argentina.

Rogers, K, Hansford, D., Sunderland, T., Brunt, A., Coish, N (2011). Measuring the ecosystem services of Torbay's trees: The Torbay i-Tree Eco pilot project. Proceedings of the ICF - Urban Tree Research Conference. Birmingham, April 13-14, 2011.

Sunderland, T., Rogers, K., Coish, N (2011). What proportion of the costs of urban trees can be justified by the carbon sequestration and air-quality benefits they provide? Arboricultural Association Conference, Warwick 2011 (Article in press).

Tiwary, A., Sinnet, D., Peachey, C., Chalabi, Z,. Vardoulakis, S., Fletcher, T., Leonardi, G., Grundy, C., Azapagic, A., T, Hutchings (2009). An integrated tool to assess the role of new planting in PM capture and the human health benefits: A case study in London. Environmental Pollution 157, 2645-2653.

Tubby, K., Rose, D (2008). Pathology Advisory Note (No 7); Problems on plane trees. Forest Research, Farnham, UK.

Zinke, P.J (1967). Forest interception studies in the United States. In: Sopper, W.E.; Lull, H.W., eds. Forest Hydrology. Oxford, UK: Pergamon Press: 137-161.

De Groot, R., Alkemade, R., Braat, L., Hein, L. And Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7, 260–270.

Kelly, M (2012). Urban trees and the green infrastructure agenda In: Johnston, M. and Percival, G. (eds.) Trees, People and the Built Environment: Proceedings of the Urban Trees Research Conference, 13–14 April 2011. The Forestry Commission, Edinburgh, pp. 18–28.

WESTMINSTER CITY COUNCIL (2009). Trees and the Public Realm. (Draft) Supplementary Planning Document. Westminster City Council

**Victoria Business Improvement District**
2nd floor, 14 Buckingham Palace Road, London SW1W 0QP

**T** 020 3004 0786     **E** info@victoriabid.co.uk
**F** 020 7821 5022     **W** www.victoriabid.co.uk