Forest Research

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Valuing the Urban Trees in Bridgend County Borough

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Forest Research is the Research Agency of the Forestry Commission and is the leading UK organisation engaged in forestry and tree related research. The Agency aims to support and enhance forestry and its role in sustainable development by providing innovative, high quality scientific research, technical support and consultancy services.

Treeconomics is a social enterprise, whose mission is to highlight the benefits of trees. Treeconomics works with businesses, communities, research organisations and public bodies to achieve this.

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

In association with:

Cyfoeth Naturiol Cymru
Natural Resources Wales

Cyngor Bwrdeistref Sirol Pen-y-bont ar Ogwr
BRIDGEND County Borough Council

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Front Cover: courtesy of Geoff Hobbs, 2015

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Executive Summary

Urban forests provide a range of services, often termed ecosystem services, that help alleviate problems associated with urbanisation. Trees improve local air quality, capture carbon, reduce flooding and cool urban environments. They provide habitat for animals, and can improve social cohesion in communities. Ecosystem service provision is directly influenced by management actions that affect the overall structure of an urban forest.

The first step to improve the management of an urban forest is to better understand its current structure, composition and distribution in order to obtain a baseline from which to set goals and to monitor progress. By measuring the structure of the urban forest (the tree species present, their size and condition), the benefits of the urban forest can be determined and the value of these benefits calculated and expressed in monetary terms. Valuing services provided by the urban trees in Bridgend County Borough (Bridgend CB) could allow Bridgend County Borough Council (Bridgend CBC) and Natural Resources Wales (NRW) to increase the profile of the urban forest thereby helping to ensure its value is maintained and improved upon.

The Bridgend CB, as described in this study, is spread across 5 separate urban districts with a total area of 4,400 ha. In order to gain a better understanding of the urban trees in Bridgend CB and to value the services they provide, an i-Tree Eco survey was undertaken in the summer of 2014. i-Tree Eco is a model developed by the US Forest Service to measure a range of ecosystem services provided by urban trees. This study was funded by NRW and Bridgend CBC and the survey was carried out by Barton Trees.

This report presents a baseline quantitative assessment of the air pollution removal, carbon storage and sequestration, rainfall interception and visual amenity of the urban forest of Bridgend CB, and is accompanied with detailed information on the forest's structure and composition. Residents in Bridgend CB benefit significantly from the urban trees present, including the **provision of ecosystem services worth £950,000 per year**. This value, however, excludes many of the ecosystem services of trees that are not currently assessed by i-Tree Eco, including cooling local air temperatures and reducing noise pollution. Therefore, this value is a conservative estimate of the ecosystem services provided. This study captures a snapshot-in-time 'picture' of the urban forest. It does not consider how the urban forest has changed over time or the reasons for this. Decisions on how the structure and composition of Bridgend CB's urban forest should change in the future or how to ensure that it is resilient to the effects of a changing climate are beyond the scope of this report, though this study goes a long way to providing the necessary baseline data required to inform such decision making.

Key Results

Bridgend County Borough's urban forest in 2014:

- had over **439,000 trees**, resulting in an average **urban tree density of 99 trees per hectare**, this is above existing estimates for other areas in the UK
- had a **12% urban tree cover**, equal to an area of 533 ha. The trees were primarily found in **parks**, on **residential land** and on **vacant land**
- had a **low proportion of large trees** compared to previous i-Tree Eco studies conducted in the UK, and would benefit from more medium and large sized trees
- had up to **27% of urban space available** to plant trees or shrubs
- included **60 tree and shrub** species, recorded across 12 land use categories
- had **ash, hawthorn** and **goat willow** as the most commonly encountered species

The trees in **Bridgend County Borough** in 2014:

- intercept an estimated **124 million litres of water** every year, equivalent to an estimated **£163,790** in sewerage charges avoided
- remove an estimated **61 tonnes of airborne pollutants** each year, worth more than **£326,000** in damage costs
- remove an estimated **2,080 tonnes of carbon** from the atmosphere each year, this amount of carbon is estimated to be **worth £461,400**
- store an estimated **53,500 tonnes of carbon**, this amount of carbon is estimated to be **worth £12.1 million**
- have a **replacement value** of **£142 million**
- have an **asset value** of **£686 million**, an evaluation based on visual amenity.

Key Conclusions

- Planning should promote a higher species diversity to create an urban forest that is resilient to pests and diseases under a present and a changing climate
- Bridgend CB's urban forest should be managed to increase the number and diversity of mature large stature trees; these are currently relatively poorly represented yet provide proportionally more ecosystem services than small stature trees
- Assessment of Bridgend CB urban forest should be repeated ca. 5 years from the date of this study.

Introduction

Urban trees provide a range of services that benefit humans, "ecosystem services". A first step to improve the management of an urban forest and maximise the benefits that it provides to humans is to undertake an urban forest assessment and quantify some of the ecosystem services provided. This can be done by using models such as i-Tree Eco, developed by the US i-Tree Cooperative[1]. i-Tree Eco has been used successfully in over 100 cities globally, has been tested for its suitability for use in the UK (Rogers et al. 2012) and has been rated as fit-for-purpose for valuing green infrastructure in the UK (Natural England 2013).

In this report, we present the findings of an i-Tree Eco survey undertaken in the urban environs of Bridgend CB, South Wales. In this section, we present an introduction to the core concepts of natural capital and ecosystem service provision required to understand the i-Tree approach to urban forest assessment.

Natural Capital and Ecosystem Service Provision

Natural capital refers to the elements of the natural environment, such as the trees and shrubs of an urban forest, that provide valuable goods, benefits and services such as clean air, food and recreation to people. As the benefits provided by natural capital are often not marketable they are generally undervalued and inventories on the natural capital are limited, where they exist at all. This may lead to wrong decisions being made about the management and maintenance of natural capital.

The ecosystem services provided to society by urban trees are introduced below:

- urban trees can play an important role in improving the health and comfort of urban residents. They provide this benefit either by absorbing and filtering pollutants and improving local air and water quality (Bolund & Hunhammar 1999), by reducing air temperatures and the so called urban heat island effect (Akbari et al. 2001) and by helping reduce stress levels and improve recovery time from illness (Ulrich 1979)
- urban trees also provide economic benefits. They store carbon, absorbing it into their tissues, helping to offset carbon emissions produced by other urban activities (Nowak *et al.* 2008). Urban trees also alleviate flash flooding, a problem that can cost cities millions of pounds each year (Bolund & Hunhammar 1999). Commercial and private property value is also increased with the addition of trees (Forestry Commission 2010)

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[1] i-Tree Co-operative: an initiative involving USDA Forest Service, Davey, Arbor Day Foundation, the Society of Municipal Arborists, International Society of Arboriculture and Casey Trees

- trees provide valuable habitat for much of the UK's urban wildlife, including bats (Entwistle et al. 2001) and bees (RHS 2012)
- they further provide local residents with a focal point to improve social cohesion and aid education with regards to environmental issues (Trees for Cities 2011).

The Millennium Ecosystem Assessment (2005) and the UK National Ecosystem Assessment (2011) provide frameworks to examine the possible goods and services that ecosystems can deliver, according to four categories: provisioning, regulating, supporting and cultural services. The ecosystem services valued by i-Tree Eco plus the other ecosystem services considered within this report are presented in Table 1. Quantifying and assessing the value of the services provided by the natural capital of Bridgend CB's urban forest will help raise the profile of the urban trees and can inform decisions that will improve human health and environmental quality.

Table 1. List of ecosystem services provided by the urban forest arranged according to the MEA categories of Provisioning, Regulating, Supporting and Cultural services. Ecosystem services considered within this report are underlined, those that are valued are also *italicised*.

Provisioning	Regulating	Supporting	Cultural
Food Wood	Climate mitigation *Carbon sequestration* *Pollution mitigation (air and water)* *Flood and water protection* Soil protection	Soil formation Biodiversity / habitats for species Oxygen production	Social cohesion *Visual amenity* Recreation, mental and physical health Landscape and sense of place Education

Table 1 shows that many of the ecosystem services provided by urban trees are not quantified or valued by i-Tree Eco. **The value of Bridgend CB urban forest presented in this report should therefore be recognised as a conservative estimate** of the value of the full range of benefits that this urban forest provides to the residents and visitors to Bridgend CB. It is also important to recognise that:

- the v5 i-Tree Eco model used in this study does not calculate projected changes in the urban forest over time or under different management regimes. It provides a snapshot-in-time picture on size, composition and condition of an urban forest. Only through comparison to previous i-Tree Eco studies, or studies using a comparable methodology, can we assess how the urban forest is changing
- air pollution data must be provided together with the field data for computation. As this data has to come from a single air quality station, monitoring all of the air

pollutants of interest and span one full calendar year, data used for modelling is not always obtained from the nearest located air quality station. For example the nearest station(s) may only monitor a sub-set of pollutants required

- i-Tree Eco is a useful tool providing essential baseline data required to inform management and policy making in support of the long term health and future of an urban forest, but does not of itself perform these tasks
- i-Tree Eco demonstrates which tree species and size class(es) are currently responsible for delivering which ecosystem services. Such information does not necessarily imply that these tree species should be used in the future. Planting and management must be informed by:
    - considerations specific to a location, such as soil quality, quantity and available growing space
    - the aims and objectives of the planting or management scheme
    - local, regional or national policy objectives
    - current climate, with due consideration given to future climate projections
    - guidelines on species composition and size class distribution for a healthy resilient urban forest.

Opportunities

The information in this report allows decision makers to:

- raise the profile of the urban forest as a key component of green infrastructure that provides many benefits and services to those who live and work in the Bridgend County Borough
- manage Bridgend CB's urban forest as an asset, with appreciable return
- plan for and finance expansion of canopy cover
- redress imbalance in species mix and age composition profiles; such changes would also help create a forest that is more resilient to the impacts of climate change
- identify risks to the tree population such as through pests and diseases, and to plan accordingly
- establish new policy to protect and expand all aspects of Bridgend CBs urban forest, including both under private and public ownership.

Links

Further details on i-Tree Eco and the full range of i-Tree tools for urban forest assessment can be found at: www.itreetools.org. The web site also includes many of the reports generated by the i-Tree Eco studies conducted around the world.

For further details on i-Tree Eco in the UK, on-going i-Tree Eco model developments, training workshops, or to download many of the reports on previous UK i-Tree Eco studies visit www.trees.org.uk (the website of the Arboricultural Association), www.treeconomics.co.uk or www.forestry.gov.uk/fr/itree.

The identification, measurement, mapping and caring for trees in the urban environment are all areas of significant opportunity for members of the general public and community groups to become 'citizen scientists'. Interested readers are referred to Treezilla: the Monster Map of Trees (www.treezilla.org) to learn more and to get involved in mapping and valuing urban trees.

Box 1. What difference can i-Tree make?

i-Tree Eco is still relatively new to the UK - the first study was conducted in Torbay, England in summer 2010. The study revealed that the ecosystem services provided by Torbay's trees were worth £1.4 million per year. This information was crucial in making the case for trees and securing an additional £25,000 to the tree budget in 2011, and again in 2014.

The impact of the London Victoria BiD i-Tree Eco study in 2011 highlighted the dependence of the community on the mature London Plane for delivery of benefits and a tree planting strategy was commissioned to seek to improve the age, size and species structure of the local tree population.

In Wrexham, the local media were so interested in the key findings of their i-Tree Eco study in 2013 that they put the value of the benefits of the local trees into the limelight before the local authority were able to issue a press release. Such a level of interest by the local press on the positive impacts of trees has not happened before.

Legislative Context in Wales

By Barbara Anglezarke (NRW)

The work to promote the wide-ranging benefits of urban woodlands and trees is now strongly underpinned by three important pieces of legislation.

Wellbeing of Future Generations (Wales) Act 2015

The Act features seven wellbeing goals with national indicators and milestones. It requires public bodies to put long-term sustainability at the forefront of their thinking, and work with each other along with other relevant organisations (such as sector groups) and the public to prevent and tackle problems. Planting and looking after trees is a key way in which we can help to safeguard the health and wellbeing of those who come after us. Public bodies will need to work towards five criteria that make up the Act's Sustainable Development Principle, which in turn will help meet the seven goals.

- **Long-term thinking** - balancing short-term needs with safeguards to meet long-term needs.
- **Prevention** - actions to prevent problems getting worse.
- **Integration** - considering how your objectives may impact on those of others.
- **Collaboration** - working with other bodies that can help you meet your goals.
- **Involvement** - involving people and communities with an interest in helping you meet your objectives, and reflecting the diversity of the people in your area.

Public bodies will need to demonstrate how they are working towards the goals. This will be through publishing wellbeing statements and responding to the Future Generations Commissioner. This will be monitored and scrutinised by the Auditor General Wales.

Environment Bill

The Bill links very closely with the Wellbeing of Future Generations Act, and it's anticipated that it will receive Royal Assent in mid-2016. It will puts in place the primary legislation needed to manage Wales's natural resources sustainably, and provides a framework for area based natural resource planning - strengthening the duty on public bodies to conserve biodiversity, and requiring NRW to lead on the development of Area Statements to translate national targets into local action. It will include a new duty for public bodies to maintain and enhance biodiversity.

Woodlands for Wales 2009 – the Welsh Government's Woodland Strategy

The Welsh Government sets out here its aspirations for urban woodlands and trees and set clear objectives in the associated Action Plan. The aim is that trees and woodlands play a greater and more valued role in towns and cities, improving quality of life and surroundings for people who live in urban areas – delivering a full range of benefits.

Methodology

i-Tree Eco uses a plot based method of sampling, with data recorded from a number of plots across a study area that are extrapolated to represent the area as a whole. Previous similar canopy cover studies have been based on aerial photography (John Clegg Consulting Ltd et al. 2007). However the plot based method, using 199 plots selected from a randomised grid covering five urban areas of Bridgend CB (Figure 1), results in higher resolution data and includes information on individual trees. The urban boundaries adopted were agreed after consultation with Bridgend County Council and Natural Resources Wales. The final study areas were defined using the Landscape Character Assessment (LCA) boundaries and Bridgend's Local Development Plan boundary (LDP). This combination was used as it included greenspaces on the periphery of the urban area and consequently outside of the LCA boundaries.

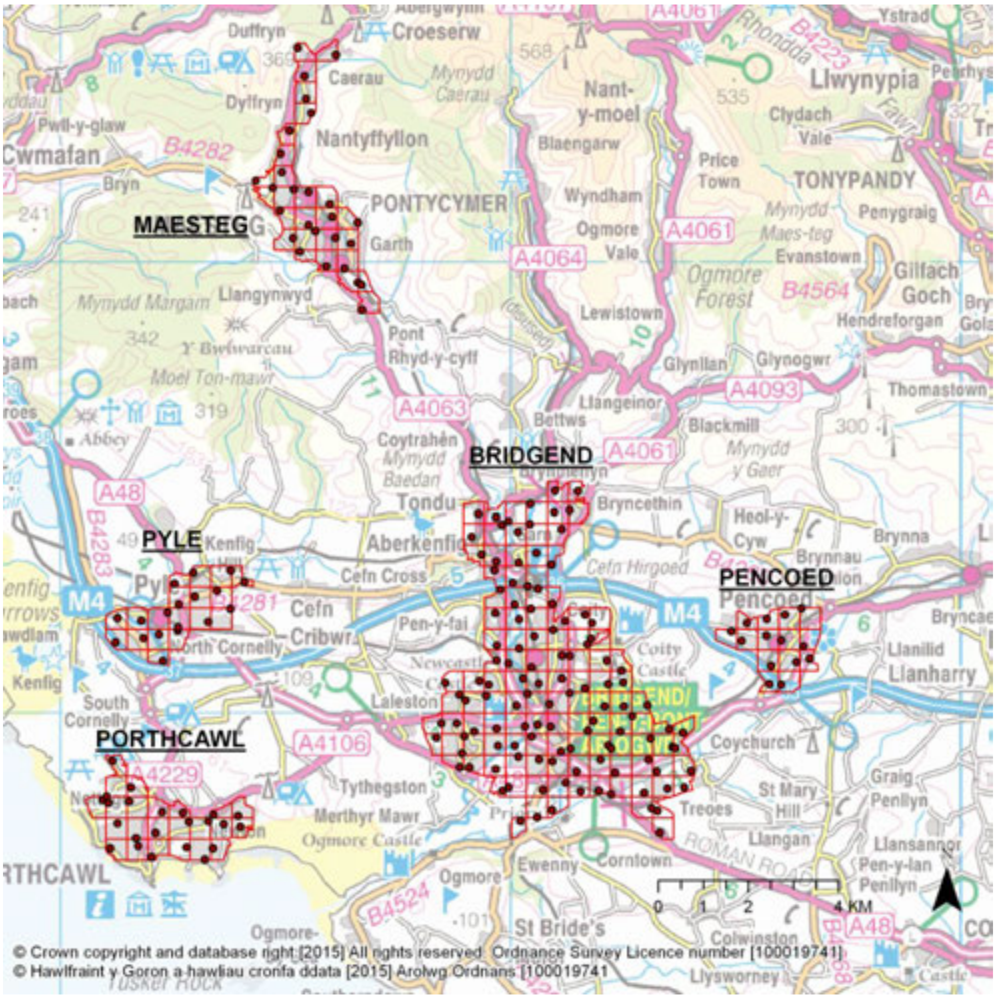

Figure 1. The five urban areas of the Bridgend County Borough i-Tree Eco survey. The sample grid and randomised plots are also shown.

The randomised grid method was chosen to overcome problems associated with patchy land use, for example aggregations of industrial units or residential properties. Grid squares present on the edge of the sample area were only allocated a sample plot if at least 50% of the grid was within the sample area.

The total sample area was 4,440 ha, resulting in one sample plot every 22 ha, similar to the sample density used in the Wrexham CB i-Tree Eco study (one per 19 ha). The proportion of plots falling into each of the different land uses is given in Figure 2.

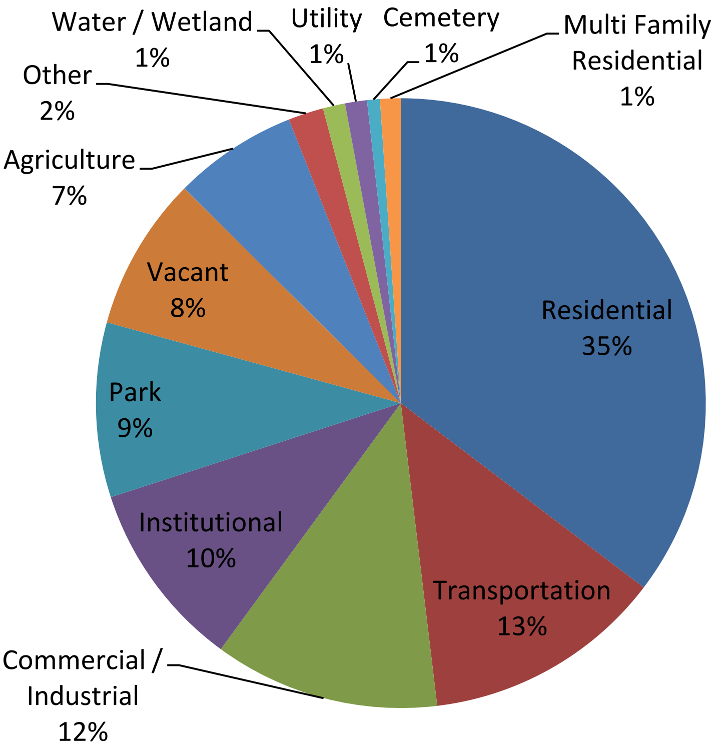

Figure 2. Proportion of plots falling into each of the different land uses. (For a definition of land-uses see Appendix 1: Table 16)

i-Tree Eco uses a standardised field collection method outlined in the i-Tree Eco Manual (v 5.0 for this study) (i-Tree 2013), and this was applied to each plot. The fieldwork was conducted in 2014.

Each plot covered 0.04 ha and from each was recorded:

- the type of land use, e.g. park, residential
- the percentage distribution of cover present in the plot e.g. grass, tarmac
- the percentage of the plot that could have trees planted in it[2]
- information about trees[3], including the
    - number of trees and their species
    - size of the trees including height, canopy spread and diameter at breast height (DBH) of trunk
    - condition of the trees including the fullness of the canopy
    - amount of light exposure the canopy receives
    - amount of impermeable surface (e.g. tarmac) under the tree
- Information about shrubs[4], including the
    - number of shrubs and their species
    - size and dimensions of the shrubs

Data collected in the field was submitted to the US Forest Service for use in the i-Tree Eco model and a number of outputs were calculated (Table 2). i-Tree Eco calculates the species and age class structure, biomass and leaf area index of the urban forest. This data is then combined with local climate, phenology and air pollution data to produce estimates of a number of ecosystem services (Table 2) and adjusted for UK Benefit Prices to assess their current and future value.

Standard i-Tree outputs are currently designed for a US audience. Thus, raw valuations are reported in terms of how ecosystem services are valued in the US and, in addition,

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[2] "Plantable space" was defined as an area that could be planted with little structural modification (i.e. permeable surfaces such as grass and soil) and that was not in close proximity to trees or buildings such as to hamper their growth.

[3] In this study, a "tree" is defined as a woody plant with a trunk diameter at breast height (DBH) that is greater than 7 cm (DBH > 7 cm)

[4] For the purposes of this study, a "shrub" is defined as a plant, woody or otherwise, with a total height over 1 m but a DBH of less than 7 cm

values are reported in US dollars. In this and other UK studies, ecosystem services were valued using the methods outlined by the UK Treasury - details are provided in the Summary of Calculations sub-section, below, and in the results sections.

Weather Data

Weather data was for the year 2013, recorded at Cardiff Bute Park weather station, approximately 30 km east of the sample area. NO_2 (2013), CO (2013), PM_{10} (2013) and $PM_{2.5}$ (2013), O_3 (ozone) (2013) and SO_2 (2013) were recorded at the Cardiff Centre station on Frederick Street, Cathays. All pollution data was obtained from www.uk-air.defra.gov.uk.

Table 2. Outputs calculated based on field collected data. Italic entries denote non-standard i-Tree Eco outputs conducted by the authors.

Urban forest structure and composition	Species diversity, canopy cover, age class, condition, importance and leaf area Urban ground cover types % leaf area by species
Ecosystem services quantified and valued	Air pollution removal by urban trees for CO, NO_2, SO_2, O_3, PM_{10} and $PM_{2.5}$ and value in £ Annual carbon sequestered and value in £ Rainfall interception and avoided sewerage charges value in £ Energy use by domestic buildings (and value estimate in £)
Replacement costs and functional values	Replacement cost based upon structural value in £ (CTLA - Council of Tree and Landscape Appraisers Method) *Replacement cost based upon amenity value in £ (a CAVAT - Capital Asset Value for Amenity Trees - assessment)* Current carbon storage value in £
Habitat provision	*Pollinating insects* *Insect herbivores*
Potential insect and disease impacts	Acute oak decline, Asian longhorn beetle, bleeding canker of horse chestnut, *Chalara* dieback of ash, *Dothistroma* (red band) needle blight, emerald ash borer, giant polypore, *gypsy moth*, oak processionary moth, *Phytophthora alni*, *Phytophthora ramorum*, *Phytophthora kernoviae*, *Phytophthora lateralis*, *spruce bark beetle*

[#] Italic entries denote non-standard i-Tree outputs conducted by the authors

Phenology Data

Leaf-on and leaf-off dates are required within the i-Tree Eco model for quantifying ecosystem service provision. Mean average leaf-on/leaf-off dates were calculated using datasets from the UK's Nature's Calendar phenology records (Woodland Trust 2014). The data from ten species were selected to calculate a UK average (field maple, sycamore, horse chestnut, common alder, silver birch, common beech, common ash, common oak, sessile oak and rowan) over a five year period (2010-2014) to provide a leaf-on date. However, because leaf-off is not in itself an event in the UK phenology database, a further average was taken from the first leaf fall and bare tree events for the ten species across the five years (2009-2013) to provide an average date for the leaf off event. The average date calculated for leaf on was April the 18th. The average date calculated for leaf off was November the 4th. Therefore, the total number of days that trees were in leaf was taken to be 201 days.

Replacement Cost and Amenity value

i-Tree Eco provides replacement costs for trees based on The CTLA (Council of Tree and Landscape Appraisers 1992) valuation method. The Capital Asset Value for Amenity Trees (CAVAT) (Nielan/LTOA 2010) method was also used in the current study. CAVAT has been developed in the UK and has been used by councils to support planning decisions. CAVAT provides a value for trees in towns, based on an extrapolated and adjusted replacement cost. This value relates to the public amenity that trees provide, rather than their worth as property (as per the CTLA method). 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 greater amenity in areas of higher population density, using official population figures. An amended CAVAT full method was chosen to assess the trees in this study, developed in conjunction with Chris Neilan – the primary author of CAVAT. A detailed methods section for both i-Tree Eco calculations and additional calculations, including CAVAT, is provided in Appendix I.

Pests and Diseases

Pest susceptibility was assessed using information on the number of trees within pathogen/pest target groups and the prevalence of the pest or disease within the UK. A risk matrix was devised for determining the potential impact of priority pests and diseases, should they become established in Bridgend CB's urban tree population. The risk matrix was adapted for use where a pest or disease targets a single genus and multiple species across more than one genera.

Habitat Provision

Trees and shrubs provide valuable habitat and food for many species, from non-vascular plants, such as moss, to insects, birds and mammals. Two examples are included: i) the importance of trees/shrubs for supporting insects generally, and ii) the importance of trees/shrubs to pollinators. Data is not available for all the tree/shrub species encountered in the Bridgend CB; only species studied in Southwood (1961), Kennedy & Southwood (1984), and RHS (2012) are included.

Summary of Calculations

Number of trees: Total number of estimated trees extrapolated from the sample plots.

Canopy cover: Total tree and shrub cover taken from direct measurements within plots.

Most common species were found based on field observations.

Pollution removal value: Calculated based on the UK social damage costs (UKSDC) and the US externality cost prices (USEC) where UK figures are not available; and these were: £1,619 per metric ton CO (carbon monoxide - USEC), £11,397 per metric ton O_3 (ozone - USEC), £12,205 per metric ton NO_2 (nitrogen dioxide - UKSDC), £1,633 per metric ton SO_2 (sulphur dioxide - UKSDC), £33,714-£66,264 per metric ton PM_{10} (Particulate matter less than 10 microns and greater than 2.5 microns - UKSDC), £7,609 per metric ton $PM_{2.5}$ (particulate matter less than 2.5 microns – USEC).

Stormwater alleviation value: The amount of water held in the tree canopy and re-evaporated after the rainfall event (avoided runoff) and not entering the water treatment system. The value is based on the 2015/16 household standard volumetric rate per cubic metre charged by Welsh Water for foul only and does not include full service; a rate of £1.3238 per m^3.

Carbon storage and carbon sequestration values: Calculated from a baseline year of 2015 and the respective 2015 DECC value of £62 per metric ton.

Building Energy saving value is calculated based on the prices of £126.7 per MWH and £11.15 per MBTU.

Replacement Cost: is the value of the trees based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree), the value is determined within i-Tree Eco according to the CTLA (Council of Tree and Landscape Appraisers) method.

Amenity Value: is calculated using the Capital Asset Valuation for Amenity Trees (CAVAT) method.

Comparisons to Other UK i-Tree Eco Studies

Comparisons of results are drawn from previous UK i-Tree Eco study reports, namely:

- Torbay (Rogers et al. 2012)
- Edinburgh City (Hutchings et al. 2012)
- Wrexham CB (Rumble et al. 2014)
- Glasgow City (Rumble et al. 2015)
- The Tawe Catchment (Doick et al. 2015)

Results and Discussion

Sample Area

Based on the sample plots in Bridgend CB, 27(±2)% of the ground cover in Bridgend CB is suitable for planting with additional trees. Tree canopy cover is 12(±2)% of the ground cover (Table 3). This finding, while slightly lower than the 15.4% canopy cover of Bridgend CB obtained via aerial photography analysis (Fryer 2014) is still comparable to that value. It is also lower than the tree canopy cover presented in the Tawe Catchment i-Tree Eco study (16%; Table 3) and the Welsh average of 16.8% (Fryer 2014), but much higher than the 8% English average reported by Britt & Johnston (2008) following a cross-section sample of 147 English towns.

The total size of Bridgend CB's urban forest is 533 ha (Table 3). This is a larger area than the 514 ha Kenfig SSSI nature reserve, north of Porthcawl (www.kenfig.org.uk) (Figure 3). Shrub cover, including shrubs below the tree canopy, is 9(±1)% of the ground cover, which is less than in the Tawe Catchment (15%) or Wrexham CB (11%) i-Tree Eco studies.

Figure 3. Bridgend CB's urban forest covers a size of 533 hectares, larger than the Kenfig SSSI nature reserve

Table 3. Outputs from the Bridgend CB i-Tree Eco survey compared to five other UK surveys.

	Location					
	Bridgend CB	Tawe Catchment	Wrexham CB	Edinburgh	Glasgow	Torbay
Study area size (ha)	4,440	6,995	3,833	11,468	17,643	6,375
Sample density (one plot per [...] ha)	22	28	19	57	88	26
Canopy cover (ha)	533	1,119	652	1,950	2,647	752
% Canopy cover	12	16	17	17	15	12
Average number of trees per ha	99	76	95	56	112	105[1]

[1] Torbay report records 128 trees per hectare, however the survey included trees with <7cm DBH which have been removed and the value recalculated for consistence in this table.

Box 2. Tree canopy cover in Bridgend County Borough

The Bridgend County Borough has a canopy cover of 12%. This is lower than the national average across Wales of 17%, and does not rank highly internationally. For example, the city of Toronto has a tree cover of 20%, New York of 21% and Barcelona has 25% tree cover. Comparison with cities at the global scale is interesting because it provides a form of benchmark; however, they should be made with caution as comparisons alone to do not provide explanations for the differences in forest structure and function, such as landscape design history. Currently, there aren't any national or internationally recognised targets for tree canopy cover in urban areas. However, 18.6% is a conservatively calculated mean cover for 26 larger European cities (Konijnendijk, 2001) and increasing canopy cover in the county borough of Bridgend will increase the amount and value of ecosystem services provided to society by trees. Increasing canopy cover through the planting and quality management of long-lived large canopy trees is likely to deliver a wider range of benefits than increasing canopy cover through planting new small canopied trees - as demonstrated throughout the remainder of this report.

Ground Cover

Ground cover in Bridgend CB consisted of 49% permeable materials, such as grass and soil; the remainder consisted of non-permeable surfaces such as tar and cement (Figure 4). Permeable surfaces can reduce problems associated with flash flooding; potentially preventing travel disruption caused by flooding as occurred in Bridgend CB in August 2013 (BBC News Wales), and reduces loads on sewer systems. At 49%, Bridgend CB has a similar percentage of permeable ground cover to that reported in the Wrexham CB, Glasgow city and Tawe catchment (53%) i-Tree Eco studies.

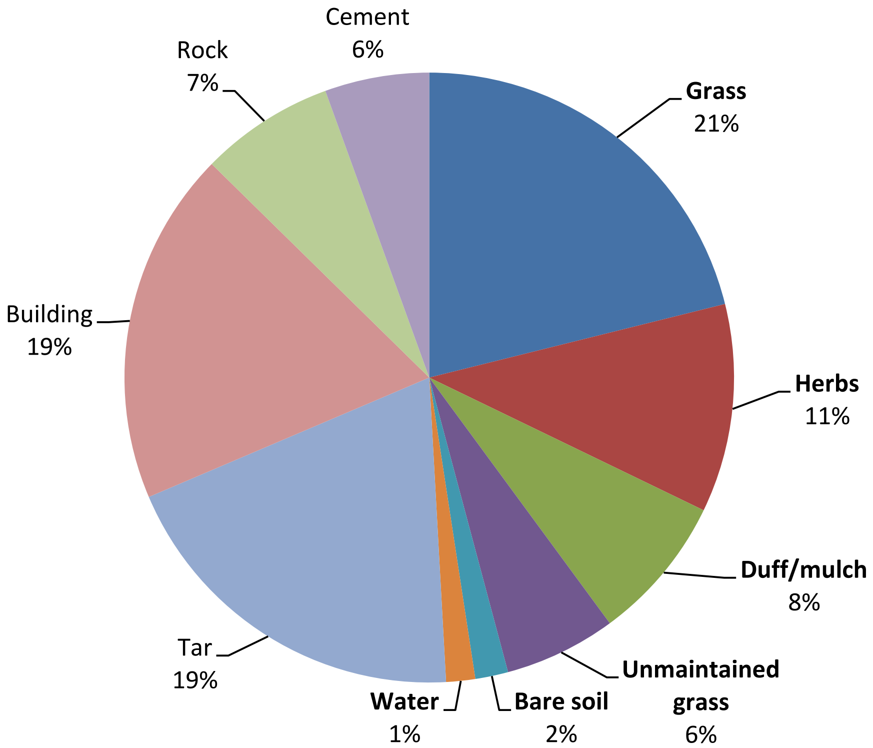

Figure 4. Types of ground cover encountered in Bridgend CB. Bold labels denote permeable surfaces, the remainder are non-permeable.

Urban Forest Structure

Species Composition

Bridgend CB's urban forest has an estimated tree population of 439,000. This is a density of 99 trees per hectare, which is higher than in the Tawe catchment (76 trees per hectare), Wrexham CB (95 trees per hectare) and Edinburgh (56 trees per hectare) i-Tree Eco studies. It is also higher than the Welsh average of 45 trees per hectare (Fryer 2014), and higher than the English average of 58 trees per hectare reported by Britt & Johnston (2008) following a cross-section sample of 147 English towns.

The three most common species are common ash, hawthorn and goat willow (Figure 5). The ten most common tree species account for 76% of the population.

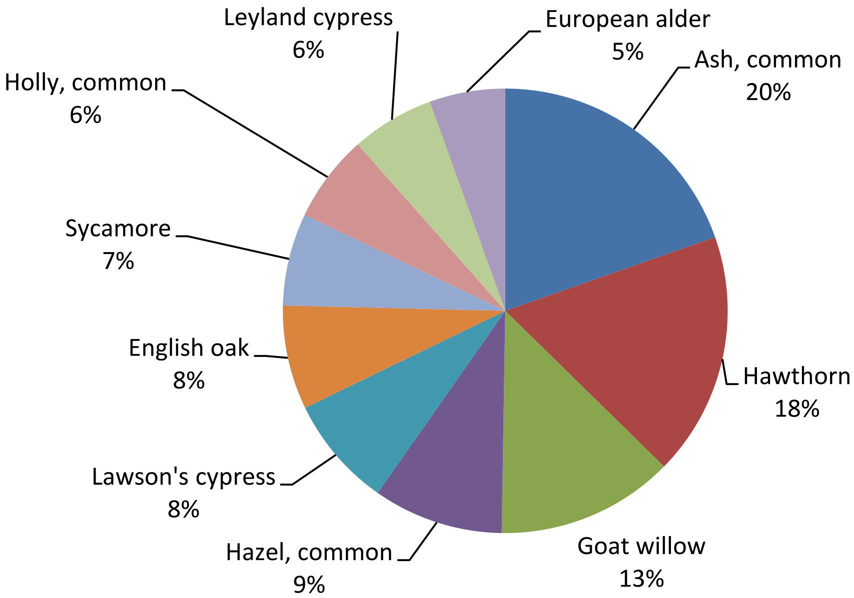

Figure 5. Breakdown of the top ten tree species in Bridgend CB.

Where trees were present, they occurred most commonly in parks (30%) on residential land (19%) and on vacant land (16%; Figure 6) - definitions for each land use are included in Appendix I (Table 16). The majority of trees are found in private ownership (55%)[5], a value higher than the one reported in the Tawe Catchment i-Tree Eco study (35%) and lower than the one reported in the Torbay (71%), Wrexham (69%) and Glasgow (76%) studies.

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[5] 'Private' includes the land-uses: residential, multi-residential, golf-courses, institutional, commercial, agriculture.

'Public' refers to the land-uses: park, transport, cemetery, vacant.

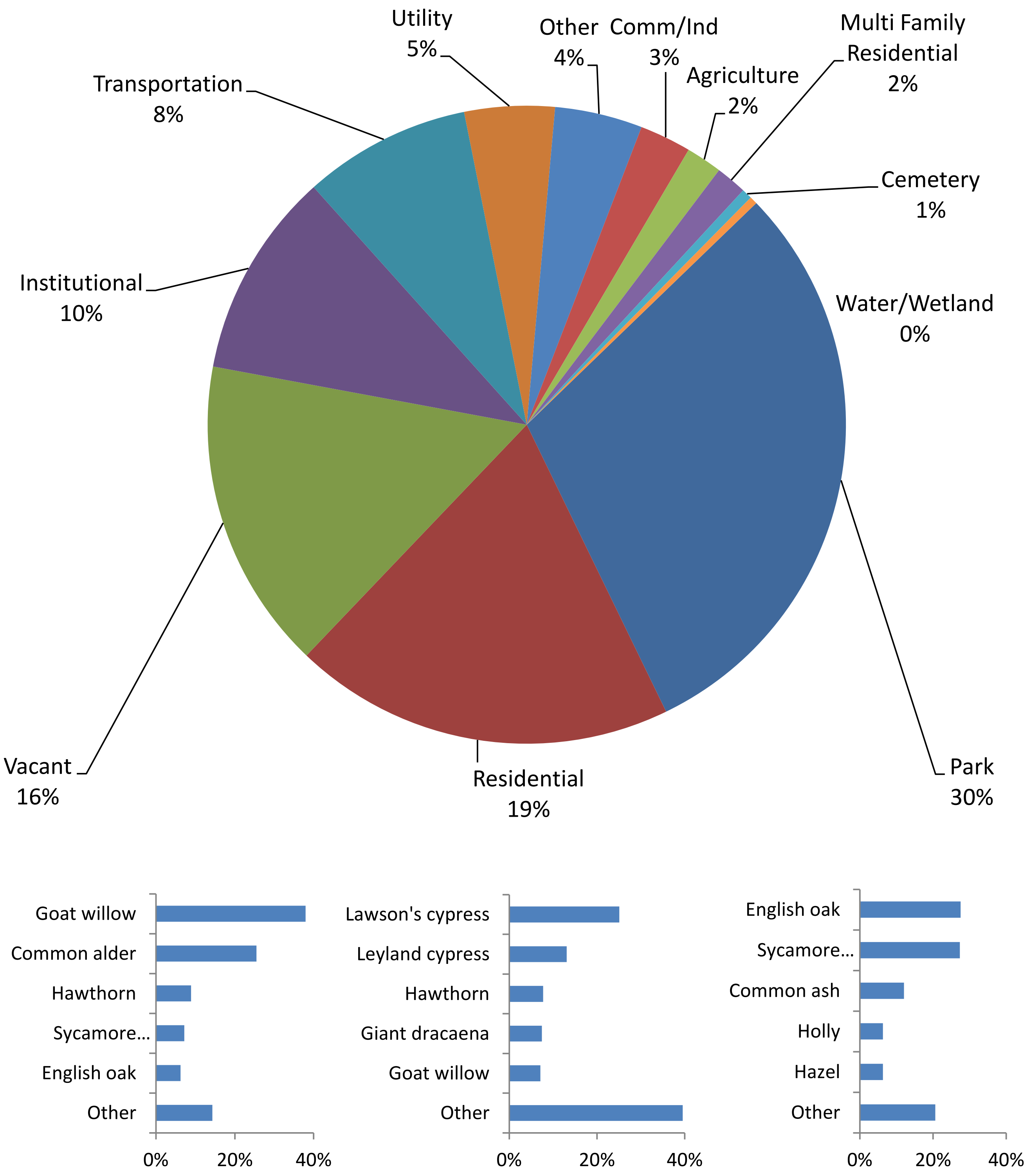

Figure 6. Land use types on which trees were present. Land uses where no trees were found are omitted. Species composition shown for the three main land uses.

Species Composition by Origin

The origin of tree species impacts on their ability to resist pests and diseases, such as the recently arrived in the UK - Chalara ash dieback, and the not yet present emerald ash borer. Additionally, prolonged exposure to drought is projected to increase due to climate change (UKCP09 2009), leaving more species weakened and vulnerable to attach by pests and diseases. These factors are leading some council's to consider the use of exotic species. Exotic species tend to have fewer pests/diseases associated with them due to being removed from the home range (Connor et al. 1980). Trees from warmer climates may also be able to withstand the effects of climate change better (RHS 2014). The debate is an on-going about whether these benefits outweigh the costs of planting exotics (Johnston et al. 2011). Exotic species can disrupt native ecosystems by changing the available niches for wildlife to fill (Townsend et al. 2008). They also support fewer native animals (Kennedy & Southwood 1984) and can become invasive due to their lower association with pests (Mitchell & Power 2003). A balance of native and non-native species may provide the most resilient solution. Of those trees identified to species level in the Bridgend CB i-Tree Eco study 74% are native to the UK and 26% are non-native[6].

Species Diversity

A total of 60 tree and shrub species were encountered during the study (for a full list see Appendix II - Species Importance List). This is more than identified in the Wrexham CB i-Tree Eco study (54 species), though less than in the Tawe catchment i-Tree Eco study (88 species). Santamour (1990) recommends that for urban forests to be resilient to pests and diseases, no species should exceed 10% of the population, no genus 20% and no family 30%. Two species exceeded the 10% guideline (ash and hawthorn). Table 4 outlines the top three species, genus and family frequencies in Bridgend CB. No genus exceeded 20% frequency and no family exceeded 30%.

Table 4. Top three frequency tree species, genus and family.

	1st		2nd		3rd	
Species	**Ash**	**14.9%**	**Hawthorn**	**13.4%**	Goat willow	6.7%
Genus	*Fraxinus*	14.9%	*Crataegus*	13.4%	*Salix*	9.9%
Family	*Rosaceae*	24.2%	*Betulacaea*	15.2%	*Oleacaea*	14.9%

Bold entries denote groups exceeding the guidelines outlined by Santamour (1990) of no species exceeding 10%, no genus 20% and no family 30%

[6] Value excludes the 13% of trees identified to genus level and so could not be assigned to a native, naturalised or non-native status

Box 3. Tree species diversity

The greatest diversity of trees in the Bridgend CB study was located on residential, park and vacant land. Given that commercial and institutional land, cemeteries and multi-residential land are typically highly managed species diversity could be increased through considered species selection, underpinned by education or policy drivers. Selecting to broaden the variety of tree species could increase the diversity offer of Bridgend CB's urban forest, and a concomitant increase in resilience in light of a changing climate, increased visual amenity value and support for biodiversity.

Diversity Index

The diversity of tree species - the number of different species present in a population and their numbers, is important because diverse populations are more resistant to pests and diseases (Johnston et al. 2011). The diversity of populations can be calculated using the Shannon-Wiener Index - a measure of the number of different species taking into account whether the population is dominated by certain species. The diversity of Bridgend CB's urban forest is 3.6 according to this index. This is marginally higher than in the Glasgow (3.3), Wrexham (3.1) and Tawe Catchment (3.0) i-Tree Eco studies. The highest diversity of trees was found in parks (3.0) and residential areas (2.9) (Figure 7).

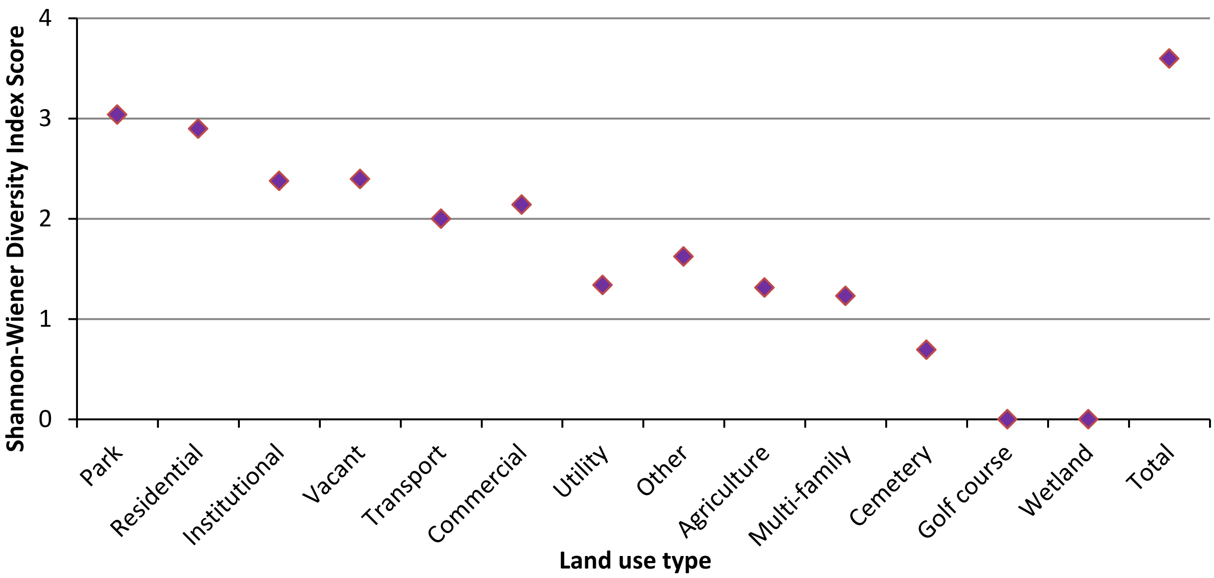

Figure 7. Shannon wiener diversity index scores for tree species identified across Bridgend CB, by land use type.

Size Class Distribution

The size distribution of trees is also important for a resilient population. Large, mature trees offer unique ecological roles not offered by small, younger trees (Lindenmayer et al. 2012). To maintain an on-going level of mature trees, young trees are also needed to restock the urban forest. New trees need to be planted in a surplus to include planning for mortality.

It is estimated that trees with a DBH less than 20 cm constitute 66% of the total tree population in Bridgend CB (Figure 8a). The number of trees in each DBH class then declines successively, where trees with DBH's higher than 60 cm make up just over 1%. Analysis of only large stature trees[7] shows that 60 cm+ diameter trees make up only 2% of the tree population (Figure 8b), which is much lower than the 10% value suggested by Richards (1983) as necessary to ensure a healthy stock of street trees. The proportion of trees with diameters between 40 and 60 cm is also low, suggesting a shortage of trees that will mature into large diameter trees in the future. Analysis of only small stature trees[8] shows that these trees make up 36% of Bridgend CB's tree population (Figure 8c). These trees will not attain large stature. They also contribute to the high numbers of trees in the lowest DBH class.

There is evidence to suggest that large trees provide more ecosystem services than small stature ones and provide more benefits compared to their costs (USDA 2003; Sunderland et al. 2012). Little work has been conducted to investigate ecosystem service provision of mature trees from small stature trees growing in dense stands, such as those hawthorn produce, so a comparison is difficult. However, it is recommended that small stature trees are supplemented with young, large stature trees to ensure a large tree component of the urban forest in the future, but retain the potential benefits that small stature thickets may provide.

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[7] Large stature trees are defined as trees that attain a maximum height greater than 10 m

[8] Small stature trees are defined as trees that do not attain height greater than 10 m

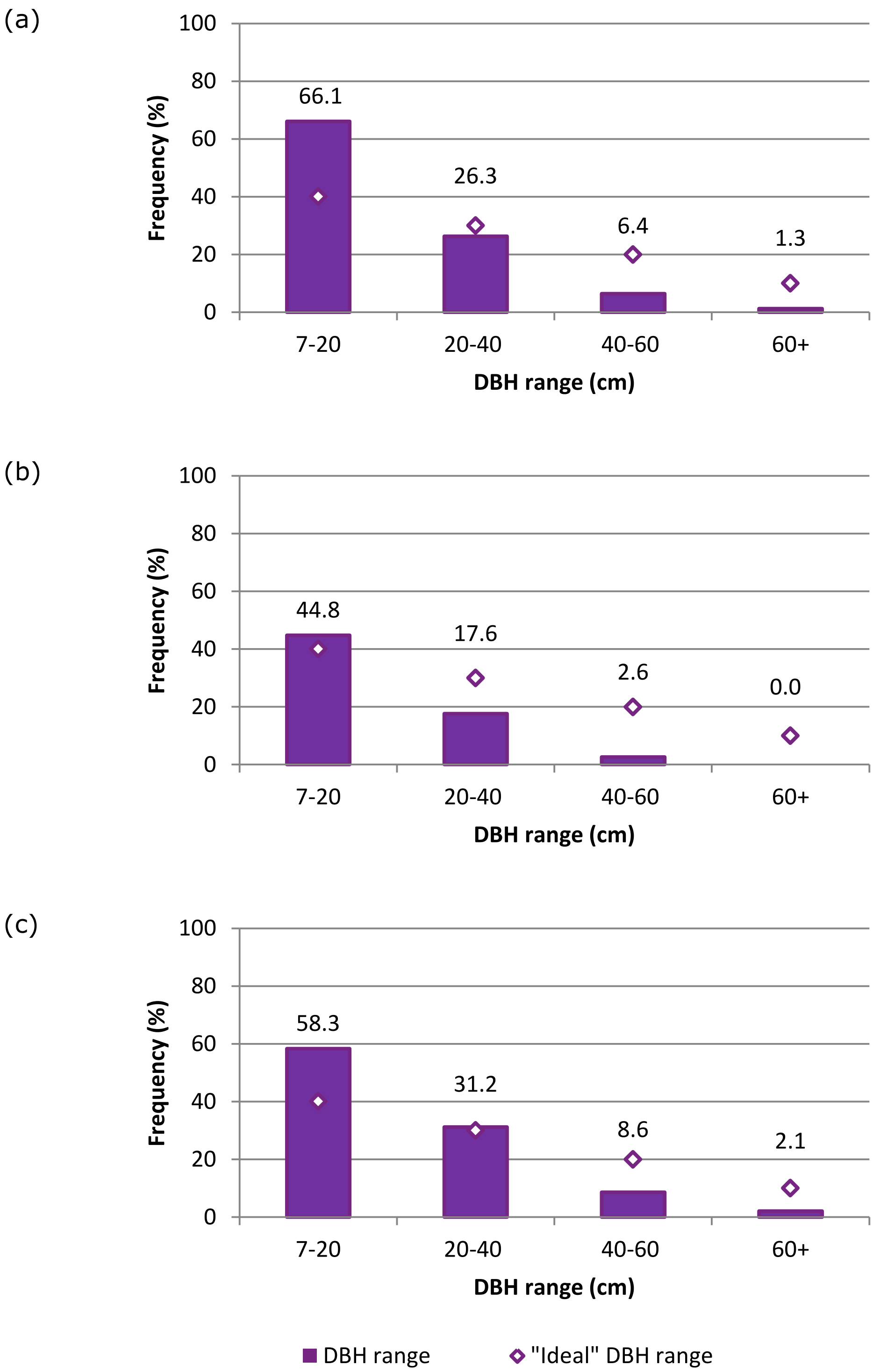

Figure 8. DBH ranges of trees (a) encountered in Bridgend CB, (b) encountered in Bridgend CB, with small stature trees removed from the analysis and (c) encountered in Bridgend CB, with medium and large stature trees removed from the analysis. Diamonds represent recommended frequencies for that DBH class as outlined by Richards (1983) i.e. 40, 30, 20, 10%.

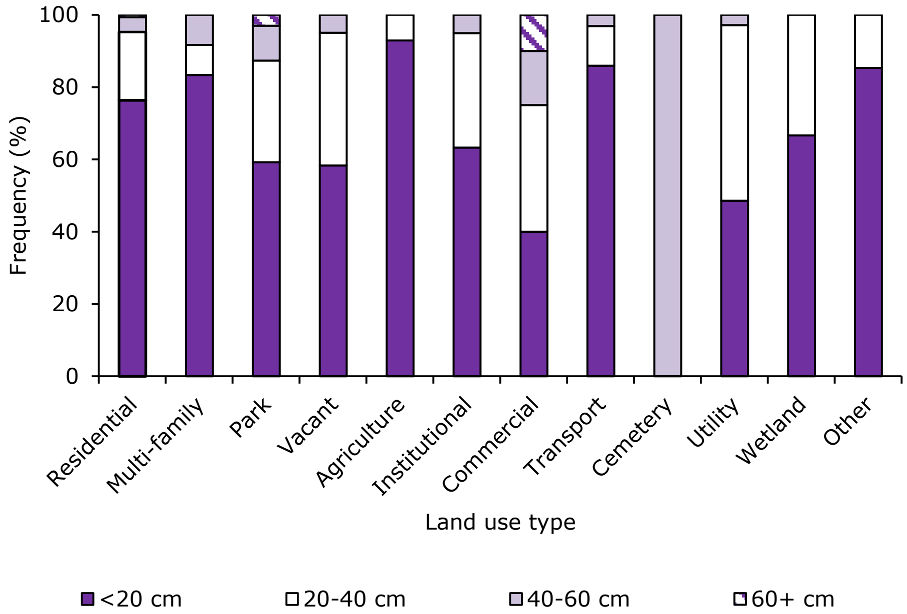

Figure 9. Proportion of diameter size classes per land use type. A missing value denotes land use types where no trees were found.

Small trees (<20 cm DBH) were highest in proportion on residential, transport and agricultural land, while large trees (>60 cm DBH) were highest in proportion on commercial and park land (Figure 9).

Box 4. Diversity in tree size

The proportion of large trees (>60 cm DBH) is low across Bridgend CB and limited to commercial land, parks and a few residential plots. In previous UK i-Tree Eco studies, such stature trees were also found on cemetery and agricultural land. In essence, the results indicate an overall deficit in large trees across Bridgend CB and, specifically, a deficit across those land uses that are the traditional strong holds of such character trees, namely, parks, cemetery, institutional and agricultural land.

The frequency of 40-60 cm DBH trees is also low across all land-use types (cemetery land being the clear exception), meaning there is a low number of trees that will grow into large stature in the short and medium terms. However, some trees in this size class are located across all but three of the land-use types (all except agriculture, wetland and 'other'). Careful management of these 40-60 cm DBH trees and investment and management to ensure a future stock of 40-60 cm DBH trees will help to improve size diversity in Bridgend CB's urban forest into the future.

Tree Condition

The condition of Bridgend CB's trees was good, with 87% of trees in excellent condition (no dieback). Only 6% of trees had more than 25% dieback (poor to dead rating) (Figure 10). Condition is a useful measure of the potential prevalence of pests or diseases and the need for further enquiry, for example targeted at specific species where obvious trends are observed; however, a stand proportion of dead trees make a valuable contribution to biodiversity, where it is safe to retain them.

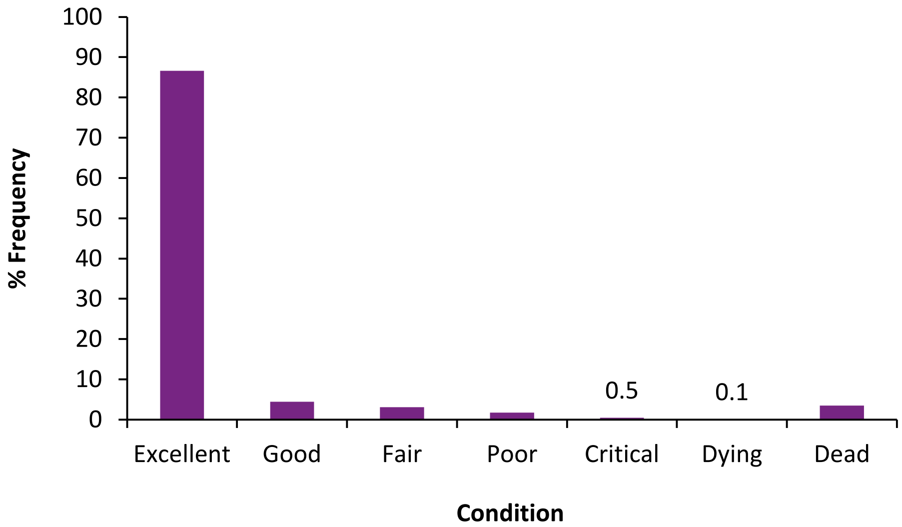

Figure 10. Condition of trees encountered in the Bridgend CB i-Tree Eco study.

Leaf Area and 'Importance Value'

The healthy leaf surface area of trees is an indicator of many of the benefits that trees can provide, including the removal of pollutants from the atmosphere (Nowak et al. 2006) and shade provision. The total leaf area provided by Bridgend CB's trees is 26 km^2 or 2,600 ha, equivalent to 5 times the size of Kenfig SSSI nature reserve. Ash, sycamore and goat willow provided the most leaf surface area (20%, 18% and 10% respectively) (Figure 11). A list of the importance values for all 60 species encountered during the study is presented in Appendix II - Species Importance List.

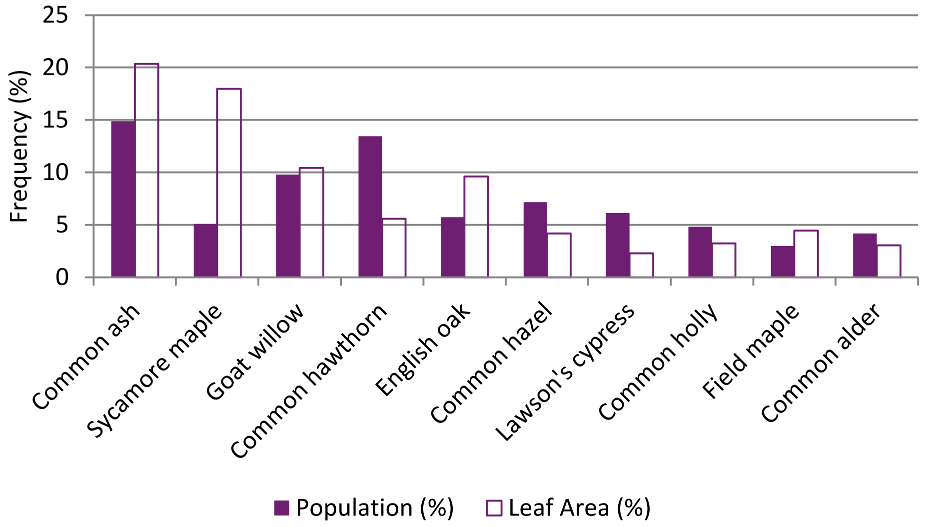

Figure 11. The top ten trees encountered in the Bridgend CB study with respect to the population size (%) and Leaf Area (%).

Importance value is calculated in i-Tree Eco as the sum of leaf-area and population size as an indication of which tree species within an urban forest are contributing most to ecosystem service provision. Trees with dense canopies and/or large leaves tend to rank highly due to their relatively large contribution to the urban forest's total leaf surface area. The top three tree species in Bridgend CB's urban forest, by importance value, were a mix of trees with dense, small leaves, such as ash and willow, and sycamore – a tree with large leaves (Table 5). Thus, the most prevalent species were not always the most important (see Figure 11 and Table 5).

Table 5. Top ten tree species encountered in the Bridgend CB study, by Importance Value (IV).

Species	IV
Common ash	35.2
Sycamore	23.1
Goat willow	20.2
Common hawthorn	19.0
English oak	15.4
Common hazel	11.4
Lawson's cypress	8.4
Common holly	8.1
Field maple	7.4
Common alder	7.2

Box 5.Tree 'Importance Value'

Importance value is calculated in i-Tree Eco as the sum of leaf-area and population size, thus trees with dense canopies and/or large leaves tend to rank highly and provide relatively more ecosystem services - Common ash and sycamore are the two most important species in this regard in Bridgend CB's urban forest. Planting more large stature trees such as oaks, limes and maples would complement ecosystem service delivery through a more species and structurally diverse urban forest. More evergreens, especially those with dense canopies, could also be included due to their year-round contribution to ecosystem service delivery.

Replacement Cost and Amenity Value

CTLA valuation

Bridgend CB's urban forest has an estimated **replacement cost value of £142 million** according to the CTLA (Council of Tree and Landscaper Appraisers) valuation method incorporated into i-Tree Eco. This is the cost of replacing Bridgend CB's urban forest should it be lost; this valuation method does not take into account the health or amenity value of trees.

CAVAT valuation

Bridgend CB's urban forest has an estimated **visual amenity asset value of £686 million** according to CAVAT (Capital Asset Value for Amenity Trees) valuation, taking into account the health of trees and their visual amenity value. The sycamore trees in Bridgend CB have the highest overall value (Figure 12, Table 6), representing 24% of the total visual amenity value of all of trees in Bridgend CB's urban forest. The single most valuable tree encountered in the study was a sycamore, estimated to have an asset value of £46,061.

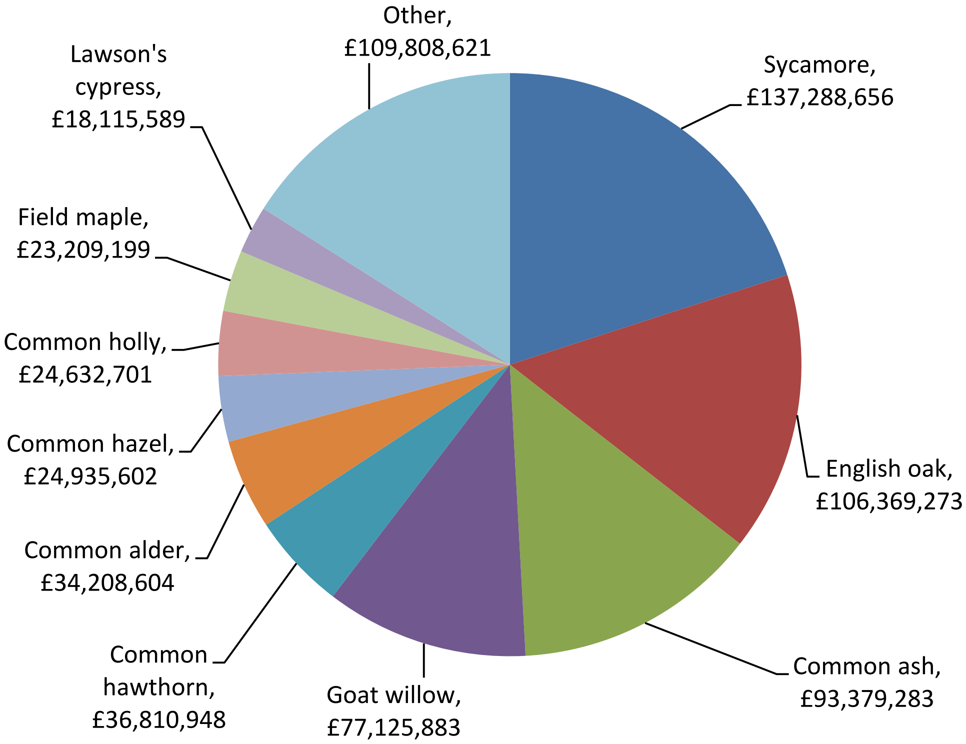

Figure 12. Monetary value held by tree species in Bridgend CB according to CAVAT analysis.

Table 6. CAVAT values for the top ten trees by genus.

Genus	Value (£) of measured trees	Total value across Bridgend CB study area
Sycamore/Maple spp	£290,962	£160,833,406
Oak spp	£196,662	£108,707,765
Ash spp	£168,932	£93,379,283
Willow spp	£139,997	£77,385,323
Hawthorn spp	£66,594	£36,810,948
Alder spp	£63,614	£35,163,304
Hazel spp	£45,111	£24,935,602
Holly spp	£44,563	£24,632,701
Cherry spp	£43,766	£24,192,358
Cypress spp	£22,586	£19,000,797
Other	£198,654	£109,808,621
Total	**£1,240,827**	**£685,884,357**

The land use type containing the highest CAVAT value of trees is parks, with over half of the total value of trees within this land use type estimated at approximately £627,400 in the plots sampled. This equates to just under £347 million when extrapolated for the whole of Bridgend CB. Water/wetland and agriculture account for the lowest value of trees at <1% of total value (Figure 13). Demonstrating which land-use types contain the most valuable trees, in respect to their visual amenity value, can help inform the policy makers, land managers and budget holders within the local authority and underpin evidenced-based decision making for a resilient urban forest into the future.

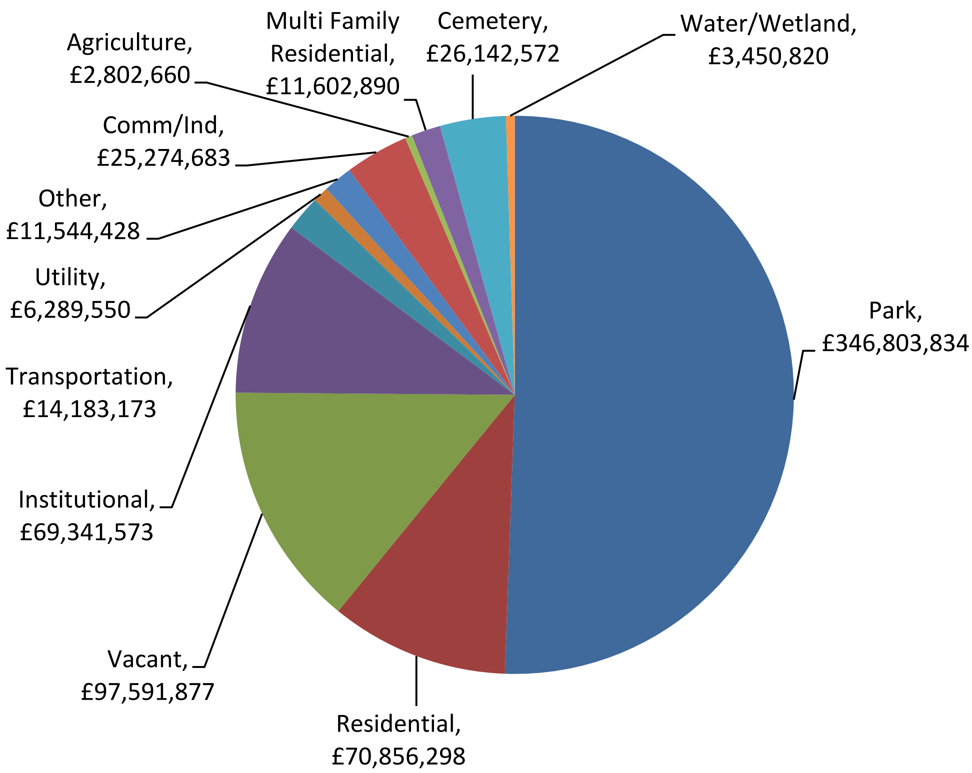

Figure 13. Monetary visual amenity value held by tree species in Bridgend CB according to land use type.

Box 6. Amenity value trees

CAVAT is designed to underpin the management of trees as assets of the local authority and to give a monetary value to individual trees, such as may be required in subsidence claims. The valuation method involves five steps, starting with determining a basic value for the trees and then adjusting in the following four steps for the tree's i) location and accessibility by the general public, ii) vitality relative to that of a well-grown healthy tree of the same species , iii) amenity and suitability to the location, which may be either positive or negative, and finally iv) according to life expectancy. Trees that have high CAVAT values are thus those of large size that are highly visible to the public, which are healthy and are well suited to the location, both in terms of their ability to grow there as well as their specific contribution to the character of the place.

Strategic selection and planting of trees according to their suitability to a location together with aftercare and management will help to ensure that the urban forest of Bridgend CB has high visual amenity in the future. Preference should be given to large stature trees where possible, especially where they are highly accessible to people, as should the selection of species with special amenity such as bark colour or canopy architecture. Selection should always be guided by local policy and suitability to the soil and location.

Avoided Surface Water Runoff

The infrastructure required to remove surface water in urban environments is costly and is out-dated in many of the towns and cities in Wales. This means that in large storm events or when water pipes fail surface water may not be removed quickly and damage to property can incur. Trees can ameliorate this problem by intercepting rainwater, retaining it on their leaves and absorbing some into their tissues for use in respiration. The roots of trees can also increase natural drainage and this is particularly important for stormwater amelioration where the surface around the trees is permeable allowing the water to infiltrate into the soil (although this is not calculated within i-Tree Eco – see Appendix I).

Bridgend CB's urban trees intercept an estimated 123,727,000 litres of water per year, equivalent to approximately 360 times the size of Pencoed or Pyle's public swimming pools[9]. Based on the standard local rate charged for sewerage[10], the presence of trees saves £163,790 in sewerage charges avoided in Bridgend CB (Table 7).

[9] Calculation assumes an average depth in the pool of 1.1 m, or a volume of 343,750 litres

Table 7. Avoided Runoff for Trees in Bridgend.

Estimated number of trees	439,000
Leaf area (km^2)	25.6
Avoided runoff (Litres / year)	123,727,000
Avoided runoff Value (£)[10]	163,790

i-Tree Eco reports the avoided surface water runoff provided by the various tree species of Bridgend CB's urban forest. Ash – a large stature tree - intercepts the most water, removing 25.2 million litres of water per year. The presence of ash saves £33,360 in sewerage charges avoided. Conversely, field maple - a small stature tree - intercepts 5.5 million litres of rain per year, saving £7,280 in sewerage charges avoided (Figure 14).

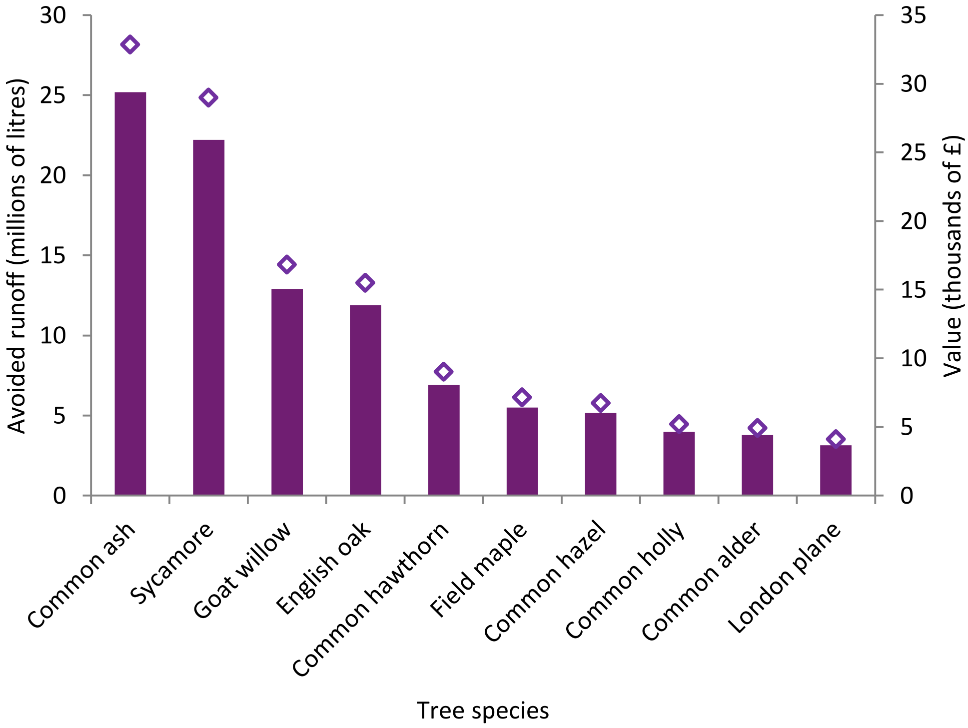

Figure 14. Avoided surface water runoff provided by urban trees in Bridgend CB (columns) and their associated value in avoided sewer costs (diamonds).

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[10] This value is based on the 2015/16 household standard volumetric rate per cubic metre charged by Welsh Water for foul only and does not include full service. This rate is stated as £1.3238 per m^3 (Welsh Water 2015)

Box 7. Rainfall interception by urban trees

Trees intercept rainfall and - by retaining it on their leaves, absorbing some into their tissues and easing drainage into and through the soil along their root canals, trees can play an important role in ameliorating the impact of stormwater and help reduce the risk of flooding. Trees with large canopies are particularly useful in this regard and across Bridgend CB ash trees, sycamores and oaks provide a valuable stormwater interception service, given their relative contributions to the total number of trees in the urban forest.

Planting of large stature trees in areas prone to flooding can complement a planning authority's strategy to flooding. Planting should occur where there is appropriate planting space and species selection must be informed by preference to the local soil, climate and hydro-geological conditions, as well as tolerance to flooding; see for example Niinemets & Valladares (2006).

Air Pollution Removal

Air pollution leads to a decline in human health, a reduction in the quality of ecosystems and it can damage buildings through the formation of acid rain (Table 8).

Trees and shrubs can ameliorate the impacts of air pollution by directly reducing airborne pollutants as well as reducing local temperatures. Trees can absorb pollutants through their stomata, or simply intercept pollutants that are retained on the plant surface (Nowak et al. 2006). This leads to year-long benefits, with bark continuing to intercept pollutants throughout winter (Nowak et al. 2006). Plants also reduce local temperatures by providing shade and by transpiring (Bolund & Hunhammar 1999), reducing the rate at which air pollutants are formed, particularly ozone (O_3; Jacob & Winner 2009). However, trees can also contribute to ozone production by emitting volatile organic compounds (VOC's) that react with pollutants (Lee et al. 2006). i-Tree reports biogenic emissions of Monoterpene and Isoprene, the most important naturally emitted VOC's (Stewart et al. 2002).

Research indicates that, of the trees present in Bridgend CB, oaks and willows have the potential to worsen air quality through release of VOC's. Whereas alder, field maple and ash remove most pollutants without contributing to the formation of new pollutants (Stewart et al. 2002). i-Tree Eco takes the release of VOC's by trees into account to calculate the net difference in ozone production and removal.

Table 8. Urban pollutants, their health effects and sources.

Pollutant	Health effects	Source
NO_2	Shortness of breath Chest pains	Fossil fuel combustion, predominantly power stations (21%) and cars (44%)
O_3	Irritation to respiratory tract, particularly for asthma sufferers	From NO_2 reacting with sunlight
SO_2	Impairs lung function Forms acid rain that acidifies freshwater and damages vegetation	Fossil fuel combustion, predominantly burning coal (50%)
CO	Long term exposure is life threatening due to its affinity with haemoglobin	Carbon combustion under low oxygen conditions i.e. in petrol cars
PM_{10} / $PM_{2.5}$	Carcinogenic Responsible for 10,000 premature deaths per year in the UK	Varied causes, cars (20%) and residential properties (20%) major contributors

Source: www.air-quality.org.uk

It is estimated that **61.2 tonnes of airborne pollutants per year are removed by Bridgend CB's urban forest**, including NO_2, O_3, SO_2, CO, PM_{10} and $PM_{2.5}$. O_3 and NO_2 were the pollutants removed in the highest volume by trees. This demonstrates that although trees can increase ozone levels by producing VOC's, they remove far more that they produce. In addition, as ozone production increases with temperature, the cooling benefits of trees reduce ozone production overall (Nowak et al. 2000).

The pollution removed from the atmosphere can be valued to aid interpretation of this data. In both the USA and the UK, pollutants are valued in terms of the damage they cause to society. However, these are valued by slightly different methods: the United States Externality Costs in the US (USEC) and the United Kingdom Social Damage Costs (UKSDC) in the UK. The UK method does not cover all airborne pollutants (Table 9) because of the uncertainty associated with the value of removing some airborne pollutants. In addition, the value of PM_{10}'s can vary depending on their emission source.

Using the UK system, which only includes three pollutants, **£325,991[11] worth of pollutants are removed** from the atmosphere each year (Table 9; Figure 15). Using the US valuation system, £629,836 worth of pollutants is removed by urban trees in Bridgend CB (Table 9).

[11] Using the lower "domestic" emission source for PM_{10}s

Table 9. Amount of each pollutant removed by the urban forest and its associated value. Dashes denote unavailable values. USEC denotes United States Externality Cost, UKSDC denotes United Kingdom Social Damage Cost.

Pollutant	Mean amount removed/tonnes per annum	US value per tonne/£	USEC value/£	UK value per tonne/£	UKSDC value/£
CO	0.3	1,619	555	*n/a*	*n/a*
NO_2	10.2	11,397	115,698	12,205 (NO_x)	123,893
O_3	36.5	11,397	416,393	*n/a*	*n/a*
PM_{10}	5.9	7,609	44,789	33,714 ($PM_{10,}$ domestic)	198,435
				66,264 ($PM_{10,}$ transport urban medium)	*390,030*
$PM_{2.5}$	6.1	7,609	46,144	*n/a*	*n/a*
SO_2	2.2	2,790	6,257	1,633 (SO_x)	3,663
Total	**61.2**		**629,836**		**325,991**[11]

n/a = not available

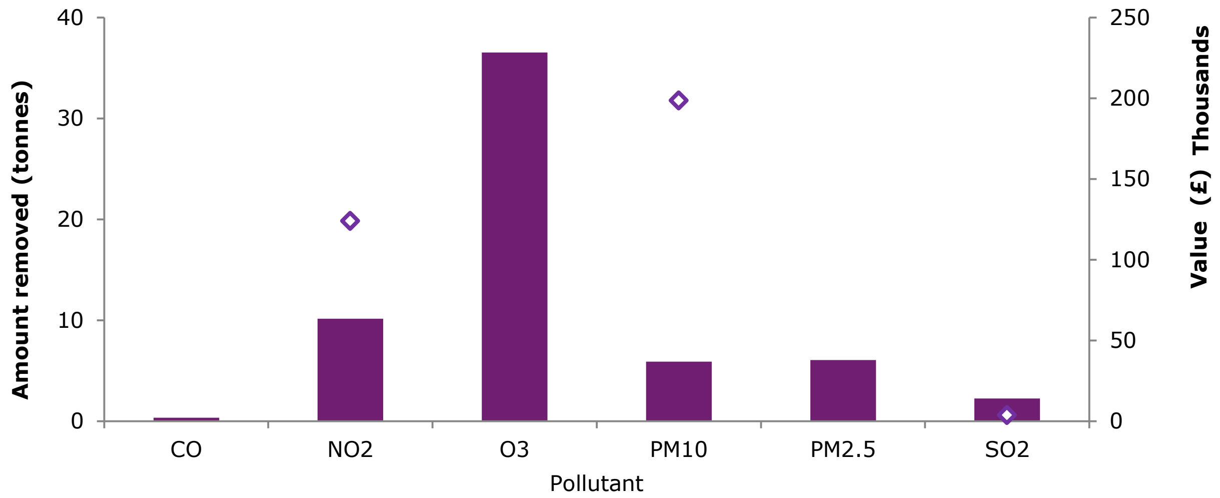


Figure 15. Mean quantity of pollutants removed by urban trees in Bridgend CB (columns) and the associated value (diamonds) as valued using the UK SDC. PM_{10} excludes $PM_{2.5}$ (i.e. particulate matter 2.5-10 microns, only).

The volume of airborne pollutants varied over the year, with a seasonal pattern evident in the removal of ozone, which was removed in higher volumes during spring and summer (Figure 16). This is because ozone is a product of the combination of NO_x, which was also removed in greater volumes in summer, and VOC's. In addition, the production of ozone follows a diurnal pattern, with ozone levels higher during the day than at night, and is more prevalent in warm temperatures (Sillman & Samson 1995).

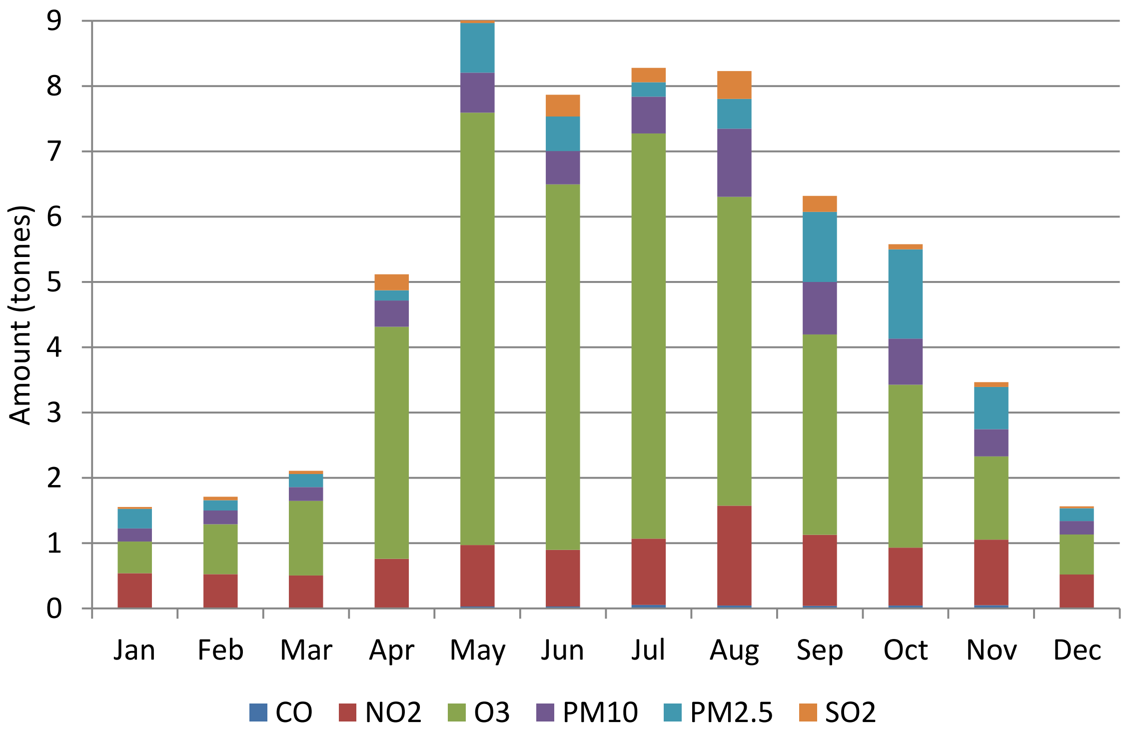


Figure 16. Amount of pollutants removed by Bridgend CB's urban trees on a monthly basis.

Box 8. Air pollution removal by urban trees

Trees can intercept airborne pollution. Some is retained on plant surfaces – leaves and bark, and some is absorbed through the stomata. By cooling local air temperatures, plants also reduce the rate at which air pollutants are formed, particularly ozone. Of the trees present in Bridgend CB, alder, field maple and ash remove the most pollutants. And while oaks and willows can detrimentally effect the air quality through release of VOCs that can contribute to the formation of new pollutants, i-Tree Eco calculates that the trees of Bridgend CB have a net positive impact on air quality – removing an estimated 61 tonnes of airborne pollutants per year.

Some recent scientific studies have shown that trees can worsen urban air quality by trapping pollutants at street level. Closer scrutiny reveals that whether trees trap air or help divert it away depends on their positioning and avoiding canopy closure over a street. It is therefore important to consider a tree's canopy architecture as well as street shape and orientation to the prevailing wind when planting street trees.

Carbon Storage

It is estimated that **Bridgend CB's trees store a total of 53,500 tonnes of carbon** in their wood. This is equivalent to 69% of the annual carbon emissions produced by Bridgend CB's households[12,13]. Alternatively, this is the equivalent of the annual CO_2 emissions of 98,500 cars[14].

Similarly to leaf area, carbon storage depends not only on the number of trees present, but also their characteristics. In this case, the mass of a tree is important, as larger trees store more carbon in their tissues. Sycamore, for example, makes up 5% of Bridgend CB's tree population but is responsible for storing 22% of the total estimated carbon stored by Bridgend CB's urban forest; hawthorn, on the other hand, stores only 5.4% of estimated carbon but makes up 13.4% of the tree population (Figure 17).

The carbon stored and sequestered by trees can be valued within the framework of the UK government's carbon valuation method (DECC 2014). This is based on the cost of the fines that would be imposed if the UK does not meet carbon reduction targets. These

[12] Based on an average UK household emission of 5 tonnes of CO_2 per year in 2009 (Palmer & Cooper 2011)

[13] Estimate based on the number of households estimated by Bridgend County Borough Council (local housing market assessment March 2009)

[14] Based on average emissions of 157g/CO_2 per km (cars registered after 2001, Department for Transport 2014), with the average UK car travelling 13,197 km per year (Department for Transport 2013)

values are split into two types, traded and non-traded. Traded values are only appropriate for industries covered by the European Union Emissions Trading Scheme. Tree stocks do not fall within this category so non-traded values are used instead. Within non-traded values, there are three pricing scenarios: low, central and high. These reflect the fact that carbon value could change due to outer circumstances, such as fuel price.

Based on the central scenario for non-traded carbon, **it is estimated that the carbon in the current tree stock is worth £12.1 million.** In 2050, this stock of carbon will be worth £31.5 million – this value assumes no change in the structure of the forest in terms of species assemblage, tree size or tree population size, and simply reflects the increased valued of non-traded carbon year-on-year to 2050. Appendix III - Non-traded values for the carbon stored in Bridgend CB's trees in all three valuation scenarios, outlines stored carbon value until 2050 for all three pricing scenarios, values do not take into account any changes that might occur to Bridgend CB's urban forest until 2050.

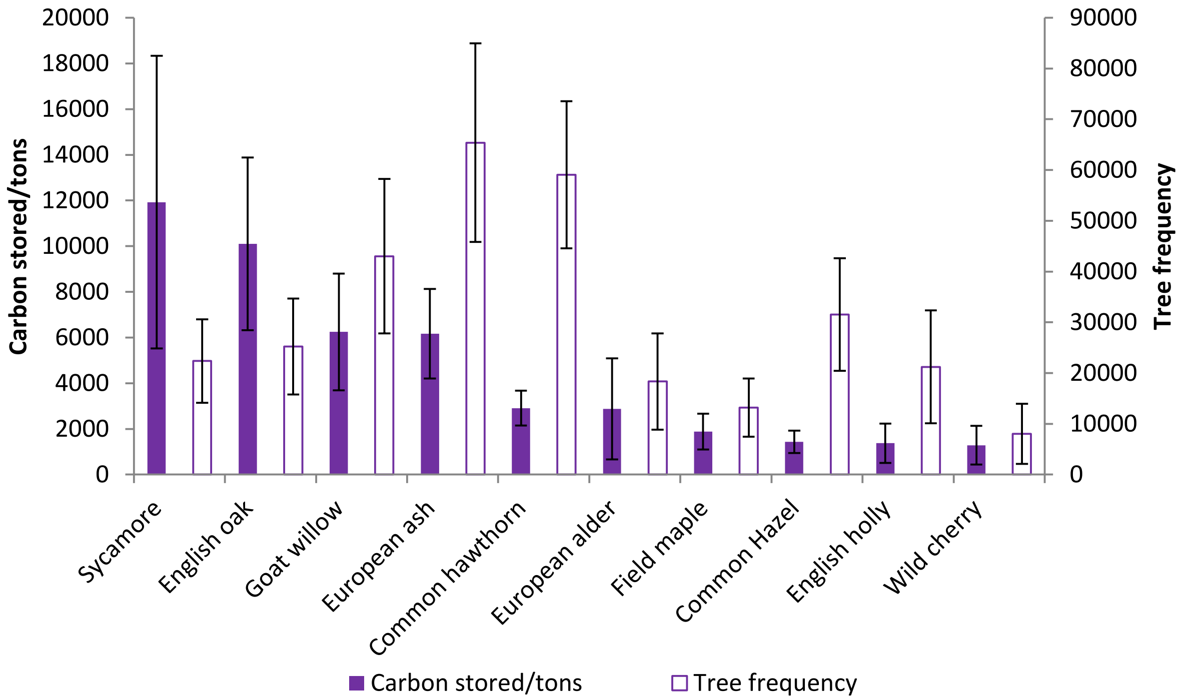


Figure 17. Amount of estimated carbon stored and the estimated frequency of each species in Bridgend CB's urban forest. Only the ten trees with the highest storage rates are displayed. Error bars denote standard error of the mean.

Carbon Sequestration

The gross amount of carbon sequestered by the urban forest in Bridgend CB each year is estimated at 2,400 tonnes. Taking into account the number of dead trees (net storage), which release carbon into the atmosphere, **Bridgend CB's urban forest sequesters 2,079 tonnes of carbon per year** (0.5 t/Ha); this **amount of carbon is estimated to be worth £461,400**. The net annual sequestration rate is equivalent to the annual emissions from 3,700 automobiles (5% of the number of cars in Bridgend CB), or 1,500 family homes (2.5% of Bridgend CB's total estimated households).

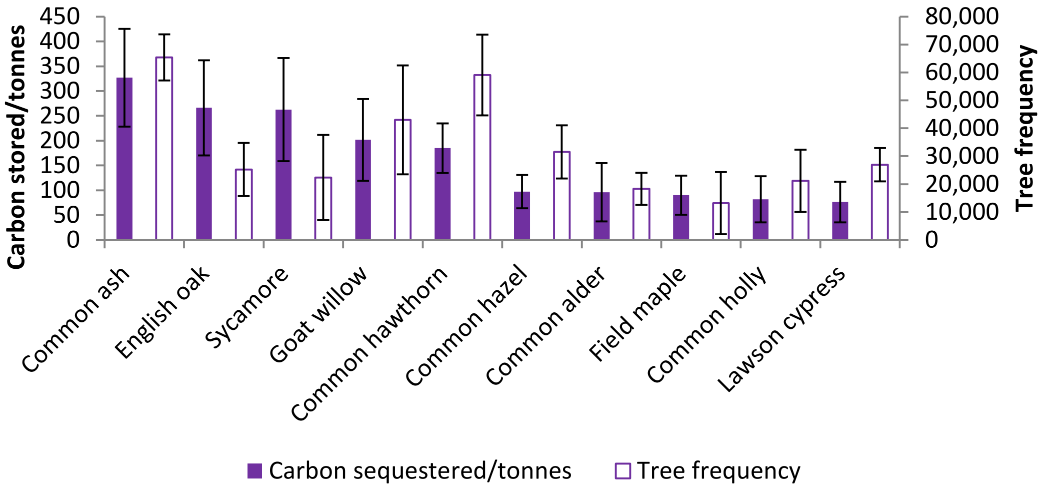


Figure 18.Estimated net carbon sequestered per year by the ten trees with highest rates, along with their estimated frequency. Error bars denote standard error of the mean.

Box 9. Carbon storage and annual sequestration

The urban forest is an important repository for carbon, both with respect to the total amount of carbon stored as well as the annual sequestration rate. By absorbing carbon dioxide from the atmosphere trees help to combat a key driver of our changing climate. This i-Tree Eco study shows that for the urban forest of Bridgend CB, the large stature trees such as sycamore and oak store a large quantity of carbon relative to their abundance. Common ash and goat willow also contribute substantially to the carbon storage by virtue of their high abundance. While the growth rate of trees in the urban environment is still subject to much research, ash, oak, sycamore and goat willow feature as the main contributors to the annual sequestration of carbon by Bridgend CB's urban forest. Future planting within Bridgend CB's urban forest should feature large stature trees because of their capacity to store large quantities of carbon over the long term, as well as quick growing and pioneer species, which will have a positive impact on carbon storage in the short-term.

Habitat Provision

Trees and shrubs provide valuable habitat and food for many animal and plant species, from non-vascular plants, such as moss Trees and shrubs provide valuable habitat and food for many animal and plant species, from non-vascular plants, such as moss, to insects, birds and mammals. Two examples are included in this section to highlight some of the organisms that trees can support: i) the importance of trees/shrubs for supporting insects generally, and ii) the importance of trees/shrubs to pollinators. For a broader review see Alexander et al. (2006).

Pollinating insects provide ecosystem services by pollinating food crops, but they are under threat from pressures including land-use intensification and climate change (Vanbergen & The Insect Pollinators Initiative 2013). Providing food sources could help. Bridgend CB's trees and shrubs are contributing to this food source, with thirty four of the genera found in Bridgend CB supporting pollinating insects (RHS 2012) (Table 10).

Many insect herbivores are supported by trees and shrubs. Some specialise on just a few tree species, whilst others are generalists that benefit from multiple tree and shrub species. Of the species found in Bridgend CB, native willows and oaks support the most varied insect herbivore species (Figure 19). Beetles, although supported by these species are better supported by Scots pine (Table 11), highlighting that some species are extremely important for certain groups.

Non-native trees associate with fewer species than native trees as they have had less time to form associations with native organisms (Kennedy & Southwood 1984). In addition, some native species form few insect herbivore associations due to their high level of defence mechanisms, yew being a good example (Daniewski et al. 1998). These species may support wildlife in other ways, for example by supplying structural habitat dead wood (buglife.org.uk 2013).

Box 10. Habitat provision by urban trees

Trees and shrubs provide valuable habitat and food for many animal and plant species, and while data availability on the role that each tree and shrub species has in supporting biodiversity found in the urban environment is far from comprehensive over-arching principles such as native trees and shrubs associate with more faunal species than non-natives can be used to plan for a resilient urban forest that complements local biodiversity. Similarly, preferential planting of species identified in Table 11 could be encouraged amongst private as well as local land owners. Local residents can be encouraged to play their part through education and awareness raising of publications by the RHS, RSPB and others on gardening for wildlife.

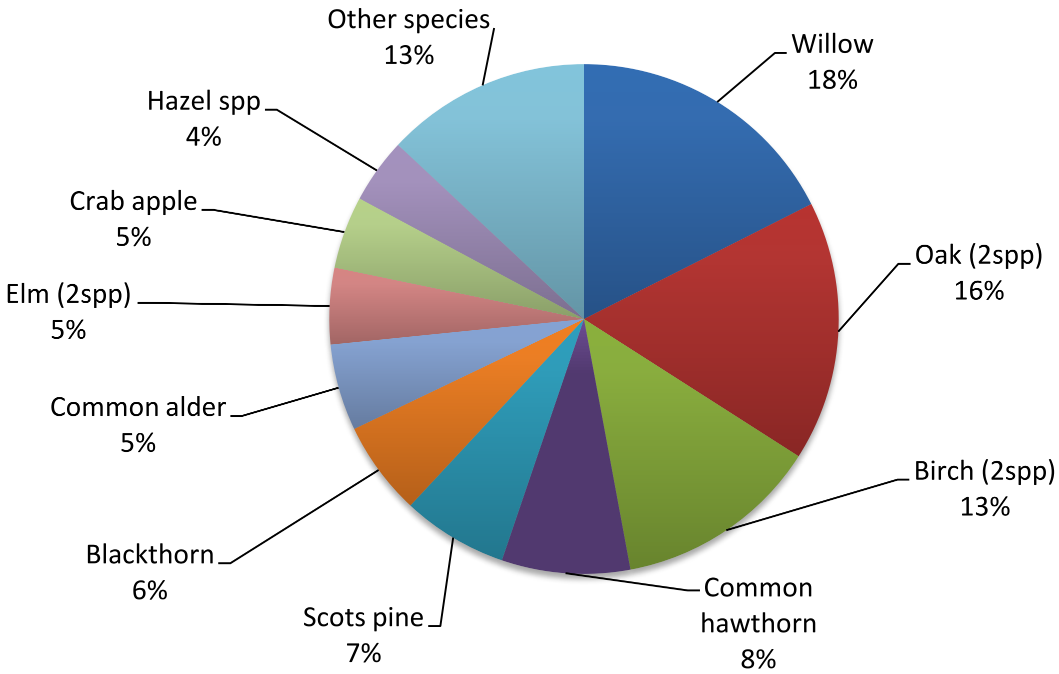


Figure 19. Relative importance of trees found in the Bridgend CB survey for supporting insects[15]. Where multiple tree species are denoted (in parentheses), insect species reflect the total associated with all hosts. Data from Southwood (1961) and Kennedy and Southwood (1984).

Table 10. Trees and shrubs encountered in the Bridgend CB survey that are beneficial to pollinators (RHS 2012).

Species	Tree/ Shrub	Season	Species	Tree/ Shrub	Season
Apple spp	Tree	Spring	Holly	Tree	Spring, Summer
Blackthorn	Tree	Spring	Horse chestnut	Tree	Spring
Common Box	Shrub	Spring, Summer	Japanese crab apple	Tree	Spring
Dogwood spp	Tree	Spring, Summer	Small leaf lime	Tree	Summer
Prunus spp	Tree	Spring	Large leaf lime	Tree	Summer
Field maple	Tree	Spring	Rowan	Tree	Summer
Goat Willow	Tree	Spring	Sycamore	Tree	Spring
Hawthorn	Tree	Spring, Summer	Wild cherry	Tree	Spring

[15] NB: Insect data is not available for all species encountered in the Bridgend CB study; only species studied in Southwood (1961) and Kennedy and Southwood (1984) are included. Even closely related species such as apples and pears are not included as data was not available for the domesticated species.

Table 11. Numbers of insect species supported by tree species (a) encountered in the Bridgend CB study and (b) for other commonly found urban tree species for which data is available#. Brightest green boxes denote tree species supporting the most insects and red denote the lowest number. Middle values are represented by a gradient between the two.

(a) Species	Scientific name	Total	Beetles	Flies	True bugs	Wasps and sawflys	Moths & butterflies	Other
Willow (5 spp)	Salix (5 spp)	450	64	34	77	104	162	9
Oak (English and Sessile)	Quercus petrea and robur	423	67	7	81	70	189	9
Birch (2 spp)	Betula (2spp)	334	57	5	42	42	179	9
Common Hawthorn	Crataegus monogyna	209	20	5	40	12	124	8
Scots Pine	Pinus sylvestris	172	87	2	25	11	41	6
Blackthorn	Prunus spinosa	153	13	2	29	7	91	11
Common Alder	Alnus glutinosa	141	16	3	32	21	60	9
Elm (2 spp)	Ulmus (2 spp)	124	15	4	33	6	55	11
Crab apple	Malus sylvestris	118	9	4	30	2	71	2
Hazel	Corylus avellana	106	18	7	19	8	48	6
Common Ash	Fraxinus excelsior	68	1	9	17	7	25	9
Mountain Ash	Sorbus aucuparia	58	8	3	6	6	33	2
Lime (2 spp)	Tilia (2 spp)	57	3	5	14	2	25	8
Field Maple	Acer campestre	51	2	5	12	2	24	6
Sycamore Maple	Acer pseudoplatanus	43	2	3	11	2	20	5
European Larch	Larix decidua	38	6	1	9	5	16	1
Holly	Ilex aquifolium	10	4	1	2	0	3	0
Horse Chestnut	Aesculus hippocastanum	9	0	0	5	0	2	2

(b) Species	Scientific name	Total	Beetles	Flies	True bugs	Wasps and sawflys	Moths & butter-flies	Other
Poplar (4 spp)	Populus (4 spp)	189	32	14	42	29	69	3
Common Beech	Fagus sylvatica	98	34	6	11	2	41	4
Norway Spruce	Picea abies	70	11	3	23	10	22	1
Common Hornbeam	Carpinus betulus	51	5	3	11	2	28	2
Juniper	Juniperis communis	32	2	5	7	1	15	2
Sweet Chestnut	Castanea sativa	11	1	0	1	0	9	0
Spruce (spp)	Abies spp	11	8	0	0	0	3	0
Common Walnut	Juglans regia	7	0	0	2	0	2	3
Yew	Taxus baccata	6	0	1	1	0	3	1
Holm Oak	Quercus ilex	5	0	0	1	0	4	0
False acacia	Robinia pseudoacacia	2	0	0	1	1	0	0

Data from Southwood (1961) and Kennedy and Southwood (1984)

Risks of Pests and Disease

Pests and diseases are a serious threat to urban forests. Severe outbreaks have occurred within living memory, with Dutch Elm Disease killing approximately 30 million trees in the UK (Webber 2010). Climate change may exacerbate this problem, ameliorating the climate for some pests and diseases, making outbreaks more likely (Forestry Commission 2014). Assessing the risk pests and diseases pose to urban forests is, therefore, of paramount importance. A risk matrix was devised for determining the potential impact of a pest or disease should it become established in Bridgend CB's urban tree population. The risk matrix was adapted for use where a pest or disease targets a single genus (Table 12) and multiple species across more than one genera (Table 13).

Table 12. Risk matrix used to assess the impact of a pest or disease on Bridgend CB's urban forest on a single genus. Green indicates a low risk, amber indicates a medium impact, and red a high impact.

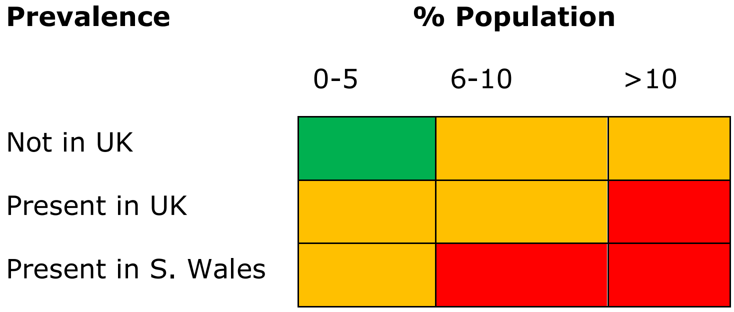
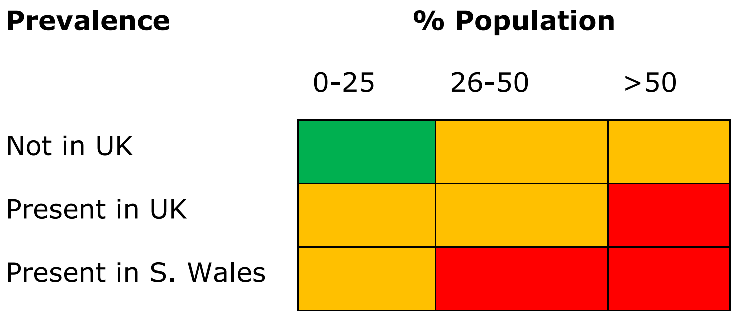


Table 13. Risk matrix used to assess the impact of a pest or disease on Bridgend CB's urban forest on multiple species across more than one genera. Green indicates a low risk, amber indicates a medium impact, and red a high impact.



With increased importation of wood and trees in addition to a climate that is becoming more amenable to many pests and diseases, ensuring urban forests are resilient is of paramount importance. The high prevalence of ash in Bridgend CB (accounting for 15% of the tree population) makes the urban forest particularly susceptible to threats such as Chalara. Protecting the urban forest as a whole against threats such as this can be helped by increasing the diversity of tree species in Bridgend CB. Other threats not yet in the UK, such as Asian longhorn beetle pose a threat to many more species and could potentially devastate a diverse range of urban trees. UK wide initiatives such as plant health restrictions are designed to combat these threats, but many pests are difficult to detect (Forestry Commission 2014). In order to protect urban forests from all pests and diseases, vigilance is key. Monitoring urban trees for signs of pests and diseases helps fast responses to eradicate pests before they are a problem and informs research targeted at combating diseases in the long term.

Table 14 gives an overview of the current and emerging pest and diseases that could affect Bridgend CB's urban forest, with a focus on those pests and diseases that lead to the death of the tree or pose a significant human health risk; further details on individual pests and diseases are provided in Appendix IV. The tables present the population of Bridgend CB's urban forest at risk from each pest and disease, the associated amenity value of these trees and the value of the carbon that they store. Subsequently, the tables highlight the relative impact of these pests and diseases and indicate the likely impact on canopy coverage and diversity of the urban forest should the pest or disease become established. The information contained in the tables can be used to inform programmes to monitor for the presence and spread of a pest or disease, and strategies to manage the risks that they pose.

Table 14. Risks of current and emerging pests and diseases.

Pest/Pathogen	Species affected	Prevalence in the UK	Prevalence in South Wales	Risk of spreading to South Wales	Population at risk/%	CAVAT value of sampled trees (£)	Stored carbon value of trees (£)
Acute oak decline	*Quercus robur*, *Q. petraea*	SE England and Midlands	Confirmed cases on the Welsh/English border	High – already present	**5.7**	192,432	2,662,268
Asian longhorn beetle	Many broadleaf species (see Appendix IV)	None (previous outbreaks contained)	None	Medium risk – climate may be suitable	**57.3**	805,868	2,765,812
Bleeding Canker of Horse Chestnut	*Aesculus hippocastanum*	Cases across the UK	Confirmed cases in urban areas	High – already present	**0.1**	5,216	1,814
Chalara dieback of ash	*Fraxinus excelsior*, *F. angustifolia*	Cases across the UK	9 confirmed cases in Wales	High - already present	**14.9**	168,932	648,710
Dothistroma (Red band) needle blight	*Pinus nigra* ssp. *laricio*, *P. contorta* var. *latifolia*, *Pinus sylvestris*	Several UK sites	Found in 4 out of 5 NRW's land management areas	High – already present	**0.5**	19,515	128,654
Emerald ash borer	*F. excelsior*, *F. angustifolia*	None	None	Medium risk (imported wood)	**14.9**	168,932	648,710
Giant polypore	*Primarily Quercus* spp., *Fagus* spp., *Aesculus* spp., *Sorbus* spp. *and Prunus* spp	Common in urban areas	Common in urban areas	High – already present	**14.2**	243,381	2,933,163
Gypsy moth	*Aesculus* spp, *Betula* spp, *Carpinus* spp, *Fagus* spp, *Quercus* spp	London, Aylesbury and Dorset	None	Medium – not present in South Wales	**9.1**	229,363	2,811,406

Table 14 (cont). Risk of current and emerging pests and diseases.

Pest/Pathogen	Species affected	Prevalence in the UK	Prevalence in South Wales	Risk of spreading to South Wales	Population at risk/%	CAVAT value of sampled trees (£)	Stored carbon value trees (£)
Oak processionary moth	*Quercus* spp.	Numerous sites in S England	None	Medium, small colonies are containable	**6.0**	196,662	2,752,014
Phytophthera alni	*Alnus* spp.	Riparian ecosytems in the UK	Heavy losses in parts of Wales	High – already present	**5.1**	63,614	424,034
Phytophthora kernoviae	*F. sylvatica, Ilex aquifolium, Q. robur, Q. ilex*ǂ	Mainly SW England and Wales	Five locations in S. Wales	High – already present	10.6	236,994	2,804,274
Phytophthora lateralis	*Chamaecyparis lawsoniana*	Cases across the UK, prevalent in W. Scotland	One confirmed case in S. Wales	High –already present	**6.1**	32,773	2,253,672
Phytophthora ramorum	*Q. cerris, Q. rubra, Q. ilex, F. sylvatica, C. sativa, Larix decidua, L. x eurolepsis*	Many UK sites, particularly in S Wales and SW England	Many cases in S. Wales	High – already present	**0.3**	6,517	34,318
Spruce bark beetle	*Picea* spp.	Mainly W England and Wales	Established in Wales	High – already present	**0.1**	607	66,251

ǂ Shrub and other tree species are also affected, some of which were found in Bridgend CB: Chilean hazelnut, *Gevina avellana;* Tulip tree, *Liriodendron tulipifera;* Winters bark, *Drimys winterii; Magnolia* spp.*; Pieris* spp.*; Michelia doltsopa;* Cherry laurel, *Prunus laurocerasus;* Ivy, *Hedera helix;* Rhododendron; Bilberry, *Vaccinium* sp

Energy Use by Buildings

i-Tree Eco models tree position, orientation and distance relative to buildings to determine the impact of the urban forest on the energy use by buildings, with respect to (winter) heating and air-conditioning (cooling) during the summer.

This 'energy-effects' model component is designed for US climate types, building types and efficiency characteristics, heating fuel types and mixes, energy production methods and emission factors. i-Tree Eco is capable of generating energy effect outputs for the UK, although has its limitations as selecting and adapting a climate region in the U.S. to the climatic conditions of the UK also means that the typical building and energy information, etc., are applied only to some extent.

Given the limitations described above, the energy effects model has not been previously used in the UK and was trialled for the first time in 2015 in the Bridgend CB, Tawe Catchment and London i-Tree Eco studies to provide an indication of the likely impact of urban trees on energy use by buildings across these study areas. The results for Bridgend CB survey are presented on a non-numeric basis in Table 15 where '+' symbols indicate a (positive) energy saving, '-' symbols indicate more energy is required (a negative energy saving) and multiple symbols indicate an order of magnitude difference. Estimates for the cost savings are detailed below, though should be used only in light of the limitations of the model to-date.

Table 15. 'Direction of travel' indicators of the likely impact of urban trees across the Bridgend CB survey area on energy use by domestic properties, where multiple symbols indicate an order of magnitude difference.

	Energy for		Total
	Heating	Cooling	
Gas	--	(n/a)#	--
Electric	--	+++	++
Carbon avoided	-	+	+
Total	---	+++	-

n/a as air conditioning units are typically electrical

With respect to a building's use of energy for heating, trees that shelter buildings from the prevailing wind offer energy savings, while trees planted to the south and west can shade a building resulting in more energy being required for heating, especially where the canopy is dense and the height to canopy base is low restricting wintertime sun from falling on to the building. With respect to buildings use of energy for cooling, trees planted to the south and west and of sufficient height can shade a building in summer, reducing the need for energy use to air condition (cool) the building. For further details on the role of trees in energy use by buildings see Doick & Hutchings (2013).

Table 15 indicates that urban trees across Bridgend CB provide substantial shading leading to a negative impact on energy use by buildings in winter (estimated as -£124,126 per year across Bridgend CB) and a positive impact with respect to summertime cooling (estimated as £117,282 per year across Bridgend CB). The overall summary suggests that the impact of the trees is slightly negative (estimated as -£6,844 per year across Bridgend CB).

To improve the role of Bridgend CB's trees with respect to efficient use of energy, the existing tree stock can be assessed for appropriate management, for example lifting of crown bases. Given the current and projected climate of Bridgend CB, adopting a strategic approach to future planting can lead to the urban forest of Bridgend CB having a positive impact on energy use for heating, as well as cooling as observed in the Tawe Catchment study (Doick et al. 2015). Homeowners and developers can follow published guidelines on the strategic placement of trees to reduce building energy use (see NHBC Foundation 2012).

Conclusions

Bridgend CB's urban forest provides valuable ecosystem services and improves the quality of life for local residents, making it a significant asset to the area. Bridgend CB is estimated to contain 439,000 trees, with a tree density per hectare greater than the one reported by other i-Tree Eco studies of a similar size. However, canopy cover was low compared to other i-Tree Eco studies. Presently, Bridgend CB also has a very low number of large diameter trees suggesting there may be a temporary shortage of large trees in the near future, and these were predominately located in three land uses - commercial, parks and residential. Large diameter trees are important because they potentially provide more ecosystem services and more habitat for wildlife than small stature trees. The potential for the presence of large trees in the longer term, however, is good given the overall condition of the urban forest and a high abundance of small diameter trees.

The ecosystem services provided by trees are on-going and services such as carbon storage could become more valuable in the future as external factors change. Planning tree stocks to maintain and enhance a high level of ecosystem service delivery is, therefore, of paramount importance. The most common species tended to be pioneer species such as hawthorn and goat willow, a pattern also found in many other i-Tree Eco surveys and reflected by the high proportion of trees found on vacant land. Some high forest species were also present in the top ten: including ash and oak. Species diversity, important for ensuring the resilience of urban trees against pests and diseases, was comparable to other UK i-Tree Eco surveys but could be improved upon. The ten most abundant tree species in Bridgend CB account for 76% of the population and two species (ash and hawthorn) exceeded the recommended limit of 10% abundance. This could lower the resilience of Bridgend CB's urban forest, particularly given the threat from *Chalara* dieback of ash. Diversity was highest on residential land and in parks, associated with the highest abundance of trees on those areas. Bridgend CB could improve the overall species diversity of the urban forest by targeting areas with lower diversity. Many of these, such as institutional properties, transport corridors and multi-family residential areas tend to be proactively managed, easing this process.

South Wales has been hit hard by numerous tree pests and diseases, most notably *Phytophthora* spp and more recently *Chalara*. Medium risk (due to climate), but high impact pests such as the Asian longhorn beetle, although not currently present in the UK, could affect many of Bridgend CB trees and there have been outbreaks in the UK that were contained. Planning an urban forest that is resilient to pests and diseases is key and can be aided by maintaining high species diversity across Bridgend CB, taking into account trees on private property in addition to those in the public realm.

The highest amenity value trees in Bridgend CB were present in parks, emphasising the importance of parks as a benefit to local residents. Highlighting the amenity value of trees within these areas could enable Bridgend CBC to demonstrate their value to potential novel funders into the future. In addition, a large proportion of Bridgend CB's trees were found on vacant land (16%). This highlights the significance that vacant land has in providing habitat for trees. For example, willow trees have a high relative importance for supporting insects and goat willow is commonly found in vacant land within Bridgend CB. However, this land is at risk from development and it is recommended that specific enquiry into the range and location of such vacant lands across Bridgend CB is conducted. This would enable the local authority to produce stronger cases for the mitigation of ecosystem services lost through development.

The carbon sequestered annually by Bridgend CB's trees is 2,400 tonnes. This information and the other values for the benefits of trees highlighted in this report can be used to shape policy or local targets for protecting existing trees and encouraging the expansion of the urban forest. The annual carbon sequestration by trees can be compared to carbon emitting practices, such as annual emissions by homes in Bridgend CB, and could then be used to inform tree planting to offset a proportion of the CO_2 emissions. In this way, tangible goals can be incorporated into local policy.

i-Tree Eco does have its limitations. Not all benefits provided by trees are quantified, including the calming effect that trees have on noise pollution, and their ability to cool urban environments. The urban forest in Bridgend CB is, therefore, far more valuable than stated in this report. Future developments in i-Tree will enable these extra benefits to supplement this report, giving a more comprehensive picture.

This study is also limited given that it is a snapshot of the forest in 2014. Monitoring, using the same technique, will allow variations to be taken into account and in the long term could be used to illustrate dynamic processes such as climate change and allow a robust long-term picture to be built. It is recommended that an i-Tree Eco survey is conducted every 5-10 years to support the management and planning of Bridgend CB's urban forest.

Bridgend CB's urban forest considerably improves the lives of inhabitants and visitors and should be valued as an asset in line with other infrastructure projects, such as roads, drainage and energy infrastructure. The urban forest provides functional services that help keep urban spaces pleasant, even sustainable, places to live. Planning and policy should reflect this, valuing trees as an integral part of our urban landscape.

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Appendix I - Detailed Methodology

i-Tree Eco Models and Field Measurements

i-Tree Eco is designed to use standardised field data from randomly located plots and hourly air pollution and meteorological data (from the geographically closest relevant monitoring station) to quantify urban forest structure and its numerous effects (Nowak and Crane, 2000), including:

- Urban forest structure (e.g., species composition, tree condition, leaf area).
- Amount of water intercepted by vegetation
- Amount of pollution removed hourly by the urban forest and its associated per cent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulphur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<10 microns; PM_{10} and <2.5 microns; $PM_{2.5}$).
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Replacement cost of the forest, as well as the value for air pollution removal, rainfall interception, and carbon storage and sequestration.
- Potential impact of potential emerging pests and diseases

All field data were collected during the leaf-on season to properly assess tree canopies. Within each plot, data collected included land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width and crown canopy missing and dieback. Definitions for each land use are presented in Table 16.

Calculating the volume of stormwater intercepted by vegetation: during precipitation events, a portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff. In urban areas, large extents of impervious surfaces can lead to highs amounts of surface runoff and to [localised] flooding during periods of high rainfall.

i-Tree Eco calculates the volume of precipitation intercepted by trees in order to enable valuation based upon, for example, flood alleviation or cost of treating surface water runoff avoided. To calculate the volume of surface runoff avoided calculations consider both precipitation interception by vegetation and runoff from previous and impervious surfaces.

To calculate the volume of precipitation intercepted by vegetation an even distribution of rain is assumed. The calculation considers the volume of water intercepted by vegetation, the volume of water dripping from the saturated canopy minus water evaporation from the canopy during the rainfall event, and the volume of water evaporated from the canopy after the rainfall event. This same process is applied to water reaching impervious ground, with saturation of the holding capacity of the ground causing surface runoff. Pervious cover is treated similarly, but with a higher storage capacity over time. The volume of avoided runoff is then summated. Processes such as the effect tree roots have on drainage through soil are not calculated as part of this model. See Hirabayashi (2013) for full methods.

The cost of treating surface water runoff avoided is not reported directly; it can, however, be inferred as the standard volumetric rate per cubic metre charge (i.e. the cost of removing, treating and disposing of used water including a charge for surface water and highway drainage) minus the standard volumetric rate–surface water rebated per cubic metre charge (i.e. the cost of removing, treating and disposing of used water). Using WW 2015/16 prices, this calculates as £1.6763 - £1.3238 = £0.35 per m^3 (i.e. the cost of managing surface water, or the surface water rebate charge).

This 'avoided charges' cost is a conservative estimate of the total 'avoided charges' across the full survey area as it does not account for infrastructural, operational and treatment charges linked to surface water management by, for example, Local Authorities, Internal Drainage Boards and Natural Resources Wales. Therefore, the Standard volumetric rate – Surface water rebated per cubic metre value of £1.3238 is used as a representative value of the avoided cost of treating surface water runoff across the whole survey area.

Table 16. Land use definitions (adapted from the i-Tree Eco v5 manual).

Land-use	Definition
Residential	Freestanding structures serving one to four families each. (Family/person domestic dwelling. Detached, semi-detached houses, bungalows, terraced housing)
Multi-family residential	Structures containing more than four residential units. (Flats, apartment blocks)
Commercial/Industrial	Standard commercial and industrial land uses, including outdoor storage/staging areas, car parks not connected with an institutional or residential use. (Retail, manufacturing, business premises)
Park	Parks, includes unmaintained as well as maintained areas. (Recreational open space, formal and informal)
Cemetery	Includes any area used predominantly for interring and/or cremating, including unmaintained areas within cemetery grounds
Golf Course	Used predominately for golf as a sport
Agriculture	Cropland, pasture, orchards, vineyards, nurseries, farmsteads and related buildings, feed lots, rangeland, woodland. (Plantations that show evidence of management activity for a specific crop or tree production are included)
Vacant	Derelict, brownfield or current development site. (Includes land with no clear intended use. Abandoned buildings and vacant structures should be classified based on their original intended use)
Institutional	Schools, hospitals/medical complexes, colleges, religious buildings, government buildings,
Utility	Power-generating facilities, sewage treatment facilities, covered and uncovered reservoirs, and empty stormwater runoff retention areas, flood control channels, conduits
Water/wetland	Streams, rivers, lakes, and other water bodies (natural or man-made). Small pools and fountains should be classified based on the adjacent land use.
Transportation	Includes limited access roadways and related greenspaces (such as motorways with acceleration/deceleration lanes, sometimes fenced); railroad stations, tracks and yards; shipyards; airports. If plot falls on other type of road, classify according to nearest adjacent land use.
Other	Land uses that do not fall into one of the categories listed above [this designation is used sparingly to prevent lack of clarity arising].

[NOTE: For mixed-use buildings land use is based on the dominant use, i.e. the use that receives the majority of the foot traffic whether or not it occupies the majority of space.]

Calculating 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*.

Calculating air pollution removal: estimates are derived from calculated hourly tree-canopy resistances for ozone and sulphur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models. As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 per cent re-suspension rate of particles back to the atmosphere.

Forest Research are currently developing growth models and leaf-area-index predictive models for urban trees in the UK. This will help improve the estimated value of the urban tree stock of Bridgend CB in the future.

Replacement costs: are based on valuation procedures of the US Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition and location information, in this case calculated using standard i-Tree inputs such as per cent canopy missing.

Calculating building energy use savings: the UFORE Methods paper states that the UFORE-E model estimates the effects of trees on building energy use and consequent emissions of carbon from power plants. For each tree within 18 m of a one or two story residential building, information on distance and direction to the building are recorded. Information for trees smaller than 6 m in height or greater than 18 m from a building are considered to have no effect on building energy use. The amount of carbon emissions from power plants avoided due to the presence of trees is calculated based upon tree size, distance, direction to building, climate region, leaf type (deciduous or evergreen) and percent cover of buildings and trees on the plot. The amount of carbon avoided is categorized into MWh (Mega Watt hours) for cooling, and MBtu (Mega British Thermal Unit[16]) and MWh for heating avoided due to tree energy effects.

Trees affect the energy performance of a building through shade, windbreak effects and local climate cooling effect. The calculations use default energy effects per tree for each climate region, vintage building types (period of construction), tree size class, distance from building, energy use (heating or cooling) and/or leaf type (deciduous or evergreen) depending upon the energy effect being modelled. For example, default shading and climate effect values are applied to all trees, while heating avoided through windbreak energy effects are only assigned to evergreen trees. Shading effect default values are only given in the model for one vintage building type (post-1980), with vintage adjustment factors applied to obtain shading effect values for all other vintage types.

US Externality and UK Social Damage Costs

The i-Tree Eco model provides figures using US externality and abatement costs. These figures reflect the cost of what it would take a technology (or machine) to carry out the same function that the trees are performing, such as removing air pollution or sequestering carbon.

In 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 (i.e. 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. The unit values used were based on those given in DECC (2011). This approach gives higher values of 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.

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. This approach is

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[16] A standard unit of measurement used to denote both the amount of heat energy in fuels and the ability of appliances and air conditioning systems to produce heating or cooling. A BTU is the amount of heat required to increase the temperature of a pint of water by one degree Fahrenheit. Since Btus are measurements of energy consumption, they can be converted directly to kilowatt-hours (3412 Btus = 1 kWh) or joules (1 Btu = 1,055.06 joules). MBtu stands for one million Btus. Ref: https://www.energyvortex.com/energydictionary/british_thermal_unit_(btu)__mbtu__mmbtu.html

termed 'the costs approach'. Values were taken from Defra (2010a) which are based on the Interdepartmental Group on Costs and Benefits (IGCB).

There are three levels of 'sensitivity' applied to the air pollution damage cost approach: 'High', 'Central' and 'Low'. This report uses the 'Central' scenario based on 2010 prices.

Furthermore, the damage costs presented exclude several key effects, as quantification and valuation is not possible or is highly uncertain. These are listed below (and should be highlighted when presenting valuation results where appropriate).

The key effects that have not been included are:

- Effects on ecosystems (through acidification, eutrophication, etc.)
- Impacts of trans-boundary pollution
- Effects on cultural or historic buildings from air pollution
- Potential additional morbidity from acute exposure to particulate matter
- Potential mortality effects in children from acute exposure to particulate matter
- Potential morbidity effects from chronic (long-term) exposure to particulate matter or other pollutants.

CAVAT Analysis

An amended CAVAT full method was chosen to assess the trees in this study, in conjunction with the creator of the system. Although the alternative "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) it was considered that the greater precision of the full method, in addition to the fact that trees other than street trees were assessed, was more appropriate in the current study.

To reach a CAVAT valuation the following was obtained:

- the current unit value factor rating
- DBH
- the Community Tree Index rating (CTI), 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 use life expectancy (SULE).

The unit value factor, which was also used in CTLA analysis, is the cost of replacing trees, presented in £/cm^2 of trunk diameter.

The CTI rating was constant across Bridgend CB at 100%. In actuality therefore, the survey concentrated on accessibility, functionality, appropriateness and SULE.

Accessibility was generally judged to be 100% for trees in parks, street trees and trees in other open areas. It was generally reduced to 80% for trees on institutional land, 40-60% on vacant plots and 40% for trees in residential areas and on agricultural land.

Because CAVAT is a method for trained, professional arboriculturalists the functionality aspect was calculated directly from the amount of canopy missing, recorded in the field. For highway trees, local factors and choices could not be taken into account, nor could the particular nature of the local street tree make-up. However, the reality that street trees have to be managed for safety, and are frequently crown lifted and reduced (to a greater or lesser extent) and that they will have lost limbs through wind damage was acknowledged. Thus, as highway trees would not be as healthy as their more open grown counterparts, and so tend to have a significantly reduced functionality, their functionality factor was reduced to 50%. This is on the conservative side of the likely range.

For trees found in open spaces, trees were divided into those with 100% exposure to light and those that did not. On the basis that trees in open spaces are less intensively managed, an 80% functionality factor was applied to all individual open grown trees. For trees without 100% exposure to light the following factor was applied: 60% to those growing in small groups and 40% to those growing in large groups. This was assumed more realistic, rather than applying a blanket value to all non-highway trees, regardless of their situation to light and/or other trees.

SULE assessment was intended to be as realistic as possible and was based on existing circumstances. For full details of the method refer to www.ltoa.org.uk/resources/cavat.

Appendix II - Species Importance List

Importance values for all species encountered during the study (see Section 'Leaf Area' in the Urban Forest Structure sub-chapter).

Rank	Species	Population (%)	Leaf Area (%)	Importance Value
1	Common ash	14.9	20.4	35.3
2	Sycamore	5.1	18.0	23.1
3	Goat willow	9.8	10.4	20.2
4	Common hawthorn	13.5	5.6	19.0
5	English oak	5.7	9.6	15.6
6	Common hazel	7.2	4.2	11.4
7	Lawson's cypress	6.1	2.3	8.4
8	Common holly	4.8	3.2	8.1
9	Field maple	3.0	4.4	7.5
10	Common alder	4.2	3.0	7.2
11	Leyland cypress	4.6	1.6	6.2
12	Silver birch	2.5	2.2	4.7
13	Wild cherry	1.8	1.1	2.9
14	London plane	0.1	2.5	2.6
15	Blackthorn	2.0	0.7	2.7
16	Common apple	1.3	0.5	1.8
17	Common plum	1.2	0.4	1.6
18	Common lime	0.3	1.2	1.5
19	Portuguese laurel	1.2	0.2	1.4
20	Scotch pine	0.4	0.9	1.3
21	European mountain ash	0.9	0.3	1.2
22	False cypress spp	0.9	0.2	1.1
23	White willow	0.1	1.0	1.1
24	European larch	0.1	0.9	1.0
25	Wych elm	0.5	0.5	1.0
26	Elderberry	0.7	0.2	0.9
27	Horse Chestnut	0.1	0.7	0.8
28	Italian alder	0.5	0.3	0.8
29	Giant dracaena	0.5	0.2	0.2
30	Swedish whitebeam	0.4	0.3	0.7
31	English elm	0.1	0.5	0.6
32	Apple spp	0.5	0.04	0.5
33	Japanese flowering Crabapple	0.4	0.2	0.6
34	Grey alder	0.4	0.2	0.6
35	Sea buckthorn	0.4	0.1	0.5
36	Pinus nigra corsicana	0.1	0.4	0.5
37	European crab apple	0.3	0.2	0.4
38	Kwanzan cherry	0.3	0.1	0.4
39	Common pear	0.1	0.3	0.4
40	Higan cherry	0.3	0.1	0.4
41	Birch spp	0.3	0.1	0.4

42	European turkey oak	0.1	0.3	0.3
43	Small-leaf lime	0.1	0.1	0.2
44	Bladder sage spp	0.1	0.1	0.2
45	Box	0.1	0.1	0.2
46	Crossopetalum spp	0.1	0.05	0.2
47	Sawara false cypress	0.1	0.05	0.2
48	Western red cedar	0.1	0.05	0.2
49	Smoke tree	0.1	0.04	0.1
50	Cypress spp	0.1	0.04	0.1
51	Lace-leaf maple	0.1	0.03	0.1
52	Giggs firethorn	0.1	0.02	0.1
53	Magnolia spp	0.1	0.02	0.1
54	Purpleleaf plum	0.1	0.02	0.1
55	Indian paper birch	0.1	0.02	0.1
56	Oak spp	0.1	0.02	0.1
57	Dogwood spp	0.1	0.02	0.1
58	Spruce spp	0.1	0.01	0.1
59	Cut leaved birch	0.1	0.00	0.1
60	Dahoon holly	0.1	0.00	0.1

Appendix III - Non-traded values for the carbon stored in Bridgend CB's trees in all three valuation scenarios

These values are based on the UK governments non-traded carbon valuation method and assume the structure of the urban forest does not change in size or composition over time.

					Non-traded unit value (£/tCO2e)					Value of discounted stored (£/tCO2e)		
Year	Stored C (t)	Net sequestered C (t)	Stored C (tCO2e)	Net sequestered C (tCO2e)	Low	Central	High	Discount rate	Discount factor	Low	Central	High
2013	53,562	2,079	196,393	7,623	30	60	90	3.5	1.00	6,067,886	12,135,773	18,203,659
2014	55,641	2,079	204,017	7,623	30	61	91	3.5	0.97	6,174,045	12,348,089	18,522,134
2015	57,720	2,079	211,640	7,623	31	62	93	3.5	0.93	6,273,289	12,546,578	18,819,867
2016	59,799	2,079	219,263	7,623	31	63	94	3.5	0.90	6,365,858	12,731,717	19,097,575
2017	61,878	2,079	226,887	7,623	32	64	95	3.5	0.87	6,451,985	12,903,970	19,355,955
2018	63,957	2,079	234,510	7,623	32	65	97	3.5	0.84	6,531,894	13,063,789	19,595,683
2019	66,036	2,079	242,134	7,623	33	66	98	3.5	0.81	6,616,652	13,233,305	19,849,957
2020	68,116	2,079	249,757	7,623	33	67	100	3.5	0.78	6,694,067	13,388,133	20,082,200
2021	70,195	2,079	257,380	7,623	34	68	102	3.5	0.75	6,764,317	13,528,634	20,292,951
2022	72,274	2,079	265,004	7,623	34	69	103	3.5	0.73	6,827,588	13,655,175	20,482,763
2023	74,353	2,079	272,627	7,623	35	70	105	3.5	0.70	6,884,066	13,768,131	20,652,197
2024	76,432	2,079	280,250	7,623	36	71	107	3.5	0.68	6,933,942	13,867,885	20,801,827
2025	78,511	2,079	287,874	7,623	36	72	108	3.5	0.65	6,977,410	13,954,820	20,932,231
2026	80,590	2,079	295,497	7,623	37	73	110	3.5	0.63	7,014,664	14,029,328	21,043,991
2027	82,669	2,079	303,120	7,623	37	74	112	3.5	0.61	7,045,899	14,091,797	21,137,696
2028	84,748	2,079	310,744	7,623	38	75	113	3.5	0.59	7,071,311	14,142,621	21,213,932

2029	86,827	2,079	318,367	7,623	38	77	115	3.5	0.57	7,640,406	15,280,811	22,921,217
2030	88,907	2,079	325,991	7,623	39	78	116	3.5	0.55	8,191,003	16,382,007	24,573,010
2031	90,986	2,079	333,614	7,623	42	85	127	3.5	0.53	8,722,651	17,445,302	26,167,954
2032	93,065	2,079	341,237	7,623	46	92	138	3.5	0.51	9,234,988	18,469,976	27,704,964
2033	95,144	2,079	348,861	7,623	50	99	149	3.5	0.49	9,727,736	19,455,473	29,183,209
2034	97,223	2,079	356,484	7,623	53	107	160	3.5	0.47	10,200,696	20,401,392	30,602,089
2035	99,302	2,079	364,107	7,623	57	114	171	3.5	0.46	10,653,739	21,307,477	31,961,216
2036	101,381	2,079	371,731	7,623	60	121	181	3.5	0.44	11,086,800	22,173,599	33,260,399
2037	103,460	2,079	379,354	7,623	64	128	192	3.5	0.43	11,499,875	22,999,750	34,499,625
2038	105,539	2,079	386,978	7,623	68	135	203	3.5	0.41	11,893,015	23,786,030	35,679,045
2039	107,618	2,079	394,601	7,623	71	143	214	3.5	0.40	12,266,319	24,532,639	36,798,958
2040	109,698	2,079	402,224	7,623	75	150	225	3.5	0.38	12,619,933	25,239,867	37,859,800
2041	111,777	2,079	409,848	7,623	78	157	235	3.5	0.37	12,954,042	25,908,084	38,862,126
2042	113,856	2,079	417,471	7,623	82	164	246	3.5	0.36	13,268,869	26,537,737	39,806,606
2043	115,935	2,079	425,094	7,623	86	171	257	3	0.35	13,634,952	27,269,903	40,904,855
2044	118,014	2,079	432,718	7,623	89	179	268	3	0.33	13,985,536	27,971,072	41,956,608
2045	120,093	2,079	440,341	7,623	93	186	279	3	0.32	14,320,670	28,641,340	42,962,010
2046	122,172	2,079	447,964	7,623	97	193	290	3	0.32	14,640,429	29,280,859	43,921,288
2047	124,251	2,079	455,588	7,623	100	200	300	3	0.31	14,944,915	29,889,831	44,834,746
2048	126,330	2,079	463,211	7,623	104	207	311	3	0.30	15,234,253	30,468,506	45,702,758
2049	128,409	2,079	470,835	7,623	107	215	322	3	0.29	6,067,886	12,135,773	18,203,659
2050	130,489	2,079	478,458	7,623	111	222	333	3	0.28	6,174,045	12,348,089	18,522,134

Calculation notes: the total amount of carbon stored and the annual sequestration rates are calculated to a baseline year of 2015.

Appendix IV – Pests and Diseases

Acute Oak Decline

Acute oak decline (AOD) affects mature trees (>50 years old) of both native oak species (common oak and sessile oak). Over the past four years, the reported incidents of stem bleeding, a potential symptom of AOD, have been increasing. The condition seems to be most prevalent in the Midlands and the South East of England, although is spreading west. There are now confirmed cases of acute oak decline on the Welsh/English border. Acute Oak Decline poses a threat to 5.7% of Bridgend CB's urban forest.

Asian Longhorn Beetle

Asian Longhorn Beetle (ALB) is a major pest in China, Japan and Korea, where it kills many broadleaved species. In America, ALB has established populations in Chicago and New York. Where the damage to street trees is high felling, sanitation and quarantine are the only viable management options.

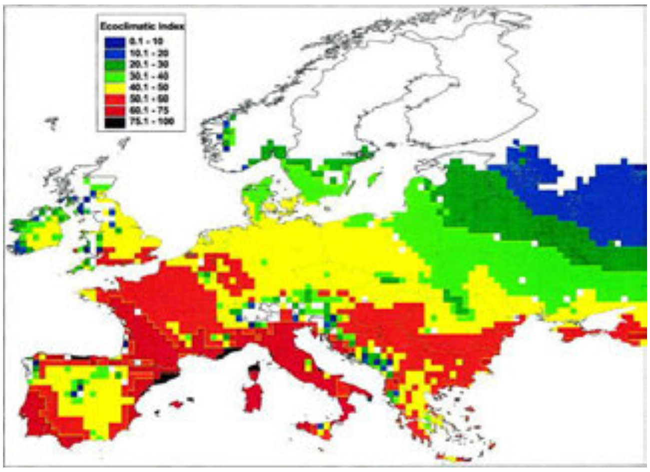

Figure 20. MacLeod *et al.,* (2002). Ecoclimatic Indices for countries across Europe. An index of >32 is suggested to be suitable for ALB.

In March 2012 an ALB outbreak was found in Maidstone, Kent. The Forestry Commission and Fera removed more than 2,000 trees from the area to contain the outbreak. No further outbreaks have been reported in the UK. MacLeod, Evans & Baker (2002) modelled climatic suitability for outbreaks based on outbreak data from China and the USA and suggested that CLIMEX (the model used) Ecoclimatic Indices of >32 could be suitable habitats for ALB. Figure 20 suggests that Bridgend CB may be amenable to ALB under this model. Analysis of climate data suggests that most of Wales and England and some warmer coastal areas of Scotland are suitable for beetle establishment, but south-east England and the south coast are at greatest risk.

If an ALB outbreak did occur in Bridgend CB it would pose a significant threat to 57.2% of Bridgend CB's trees, not including attacks on shrub species.

The known host tree and shrub species include:

Acer spp. *(maples and sycamores)*

Aesculus spp. *(horse chestnut)*

Albizia spp. *(Mimosa, silk tree)*

Alnus spp. *(alder)*

Betula spp. *(birch)*

Carpinus spp. *(hornbeam)*

Cercidiphyllum japonicum (Katsura tree)

Corylus spp. *(hazel)*

Fagus spp. *(beech)*

Fraxinus spp. *(ash)*

Koelreuteria paniculata

Platanus spp. *(plane)*

Populus spp. *(poplar)*

Prunus spp. *(cherry, plum)*

Robinia pseudoacacia (false acacia/black locust)

Salix spp. *(willow, sallow)*

Sophora spp. *(Pagoda tree)*

Sorbus spp. *(mountain ash/rowan, whitebeam etc)*

Quercus palustris (American pin oak)

Quercus rubra (North American red oak)

Ulmus spp. *(elm)*

Bleeding Canker of Horse Chestnut

The pathogen *Pseudomonas syringae* pv *aesculi* causes bleeding canker of horse chestnut (BCHC), causing stem bleeding. The resultant loss of bark can lead to girdling and everntually death, particularly in young trees. In 2007, the Forestry Commission undertook a survey of BCHC in the UK and found that 41% of urban trees in Wales showed symptoms to some degree, compared to 32% in rural areas. 0.1% of Bridgend CB's urban trees are susceptible to BCHC.

Chalara Dieback of Ash

Ash dieback, caused by the fungus *Chalara fraxinea*, targets common and narrow leaved ash. Young trees are particularly susceptible and can be killed within one growing season of symptoms becoming visible. Older trees take longer to succumb, but can die from the infection after several seasons. *C. fraxinea* was first recorded in the UK in 2012 in Buckinghamshire and has now been reported across the UK, including in urban areas. There are nine confirmed cases in South Wales since 2013. Ash dieback poses a threat to 14.9% of Bridgend CB's urban forest.

Dothistroma Needle Blight

Dothistroma (red band) needle blight is the most significant disease of coniferous trees in the North of the UK. The disease causes premature needle defoliation, resulting in loss of yield and, in severe cases, tree death. It is now found in many forests growing susceptible pine species, with Corsican, lodgepole and, more recently, Scots pine all being affected. It has been found in three of the four Natural Resources Wales' land management areas. However, there are no reported cases of red band needle blight on urban trees and only 0.5% of Bridgend CB's urban forest are at threat from it.

Emerald Ash Borer

There is no evidence to date that emerald ash borer (EAB) is present in the UK, but the increase in global movement of imported wood and wood packaging poses a significant risk of its accidental introduction. EAB is present in Russia and is moving West and South at a rate of 30-40 km per year, perhaps aided by vehicles (Straw et al. 2013). EAB has had a devastating effect in the USA due to its accidental introduction and could add to pressures already imposed on ash trees from diseases such as Chalara dieback of ash. Emerald Ash borer poses a potential future threat to 14.9% of Bridgend CB's urban forest.

Giant Polypore

Giant polypore (*Meripilus giganteus)* is a fungus that can cause internal decay in trees without any external symptoms (Schmidt 2006), causing trees to potentially topple or collapse (Adlam 2014). It is particularly common in urban areas and can also cause defoliation and crown dieback (Schmidt 2006; Adlam 2014). Giant polypore predominantly affects hardwoods such as horse chestnut, beech, mountain ash, cherry and oak. 9.8% of Bridgend CB's urban forest could be susceptible to giant polypore.

Great spruce bark beetle (*Dendroctonus micans*)

The great spruce bark beetle damages spruce trees by tunnelling into the bark of the living trees to lay its eggs under the bark, and the developing larvae feed on the inner woody layers. This weakens, and in some cases can kill, the tree. It has become an established pest in Wales but only poses a 0.1% threat to Bridgend CB's urban forest.

Gypsy Moth

Gypsy moth (GM), *Lymantria dispar*, is an important defoliator of a very wide range of trees and shrubs in mainland Europe, where it periodically reaches outbreak numbers. It can cause tree death if successive, serious defoliation occurs on a single tree. A small colony has persisted in northeast London since 1995 and a second breeding colony was found in Aylesbury, Buckinghamshire in the summer of 2005. Aside from these disparate colonies, GMs range in Europe does not reach as far West as the UK. Some researchers suggest that the climate in the UK is currently suitable for GM should it arrive here and that it would become more so if global temperatures rise (Vanhanen *et* al., 2007). However, the spread of gypsy moth in the USA has been slow, invading less than a third of its potential range (Morin *et al*., 2005). If GM spread to Wales, it would pose a threat to 9.1% of Bridgend CB's urban trees.

Oak Processionary Moth

It was first accidentally introduced to Britain in 2005, and it is theoretically possible that if it were to spread it could survive and breed in much of England and Wales. Established breeding populations of oak processionary moth (OPM) have been found in South and South West London and in Berkshire. It is thought that OPM has been spread on nursery trees. The caterpillars cause serious defoliation of oak trees, their principal host, but the trees will recover and leaf the following year. On the continent, they have also been associated with hornbeam, hazel, beech, sweet chestnut and birch, but usually only where there is heavy infestation of nearby oak trees. The caterpillars have urticating (irritating) hairs that carry a toxin that can be blown in the wind and cause serious irritation to the skin, eyes and bronchial tubes of humans and animals. They are considered a significant human health problem when populations reach outbreak proportions, such as those in The Netherlands and Belgium have done in recent years. The outbreak in London is beyond eradicating, however there are efforts to stop the spread out of London and minimise the impact. There have been no confirmed cases found in Wales to date. Oak processionary moth poses a threat to 6.0% of Bridgend CB's urban forest.

Phytophthora alni

All alder species in Britain are threatened by a lethal disease first discovered in the country in 1993. *Phytophthora* disease of alder is now widespread in the riparian ecosystems in the UK where alder commonly grows. On average, the disease incidence is highest is southeast England. However, heavy losses are occurring in some of the large alder populations that occur along western rivers – for example, in the Marches and parts of Wales. Phytophthora alni poses a risk to 5.1% of Bridgend CB's urban forest.

Phytophthora kernoviae

Phytophthora kernoviae (PK) was first discovered in Cornwall in 2003. The disease primarily infects rhododendron and bilberry (*Vaccinium*) and can cause lethal stem cankers on beech. It was found in five locations in South Wales in 2005 but has since been contained. *Phytophthora kernoviae* is deemed to pose a risk to 10.6% of Bridgend CB's urban forest and affects many of Bridgend CB's shrub species.

Phytophthora lateralis

The main host of *Phytophthora lateralis* (PL) is Lawson cypress. It has resulted in the decline of Lawson cypress hedgerows, with lesions spreading up the lower stem, resulting in crown death. Although there are less than 2,200 hectares of commercially grown Lawson cypress in Britain, there is a huge risk to amenity and garden populations. One case of PL infection has been reported since April 2014 in South Wales. *Phytophthora lateralis* is deemed to pose a risk to 6.1% of Bridgend CB's urban forest.

Phytophthora ramorum

Phytophthora ramorum (PR) was first found in the UK in 2002 and primarily affects species of oak (Turkey oak, Red oak and Holm oak), beech and sweet chestnut. However, it has also been known to occasionally infect European and hybrid larch and kills Japanese larch. Rhododendron is a major host, which aids the spread of the disease. South Wales has seen numerous cases of PR in forest stands. South Wales including Bridgend CB are within the Forestry Commission's Core Disease Zone. *Phytophthora ramorum* poses a threat to 0.3% of Bridgend CB's urban forest.

Glossary of Terms

Biomass - the amount of living matter in a given habitat, expressed either as the weight of organisms per unit area or as the volume of organisms per unit volume of habitat

Broadleaf species – for example, alder, ash, beech, birch, cherry, elm, hornbeam, oak, other broadleaves, poplar, Spanish chestnut, and sycamore

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

Crown – the part of a plant that is the totality of the plant's above-ground parts, including stems, leaves, and reproductive structures

Defoliator(s) – pests that chew portions of leaves or stems, stripping of chewing the foliage of plants (e.g. Leaf Beetles, Flea Beetles, Caterpillars, Grasshoppers)

Deposition velocities - dry deposition: the quotient of the flux of a particular species to the surface (in units of concentration per unit area per unit time) and the concentration of the species at a specified reference height, typically 1m

Diameter at Breast Height (DBH) – the outside bark diameter at breast height. Breast height is defined as 4.5 feet (1.37m) above the forest floor on the uphill side of the tree. For the purposes of determining breast height, the forest floor includes the duff layer that may be present, but does not include unincorporated woody debris that may rise above the ground line

Dieback – where a plant’s stems die, beginning at the tips, for a part of their length. Various causes.

Ecosystem services - benefits people obtain from ecosystems

Height to crown base - the height on the main stem or trunk of a tree representing the bottom of the live crown, with the bottom of the live crown defined in various ways

Leaf area index - the ratio of total upper leaf surface of vegetation divided by the surface area of the land on which the vegetation grows

Lesions - any abnormal tissue found on or in an organism, usually damaged by disease or trauma

Meteorological - phenomena of the atmosphere or weather

Particulate matter - a mixture of solid particles and liquid droplets suspended in the air. These particles originate from a variety of sources, such as power plants, industrial processes and diesel trucks. They are formed in the atmosphere by transformation of gaseous emissions

Pathogen - any organism or substance, especially a microorganism, capable of causing disease, such as bacteria, viruses, protozoa or fungi

Phenology - the scientific study of periodic biological phenomena, such as flowering, breeding, and migration, in relation to climatic conditions

Re-suspension - the remixing of sediment particles and pollutants back into the air, or into water by wind, currents, organisms, and human activities

Stem cankers - a disease of plants characterized by cankers on the stems and twigs and caused by any of several fungi

Structural values - value based on the physical resource itself (e.g. the cost of having to replace a tree with a similar tree)

Trans-boundary pollution - air pollution that travels from one jurisdiction to another, often crossing state or international boundaries

Transpiration - the evaporation of water from aerial parts of plants, especially leaves but also stems, flowers and fruits

Tree-canopy - the above-ground portion of a plant community or crop, formed by plant crowns

Tree dry-weight – tree material dried to remove all the water

Urticating Hairs - are possessed by some arachnids (specifically tarantulas) and insects (most notably larvae of some butterflies and moths). The hairs have barbs which cause the hair to work its way into the skin of a vertebrate. They are therefore an effective defence against predation by mammals

Volatile organic compounds - one of several organic compounds which are released to the atmosphere by plants or through vaporization of oil products, and which are chemically reactive and are involved in the chemistry of tropospheric ozone production.