URBAN FOREST 1066

ASSESSING THE IMPORTANCE AND VALUE OF TREES

Rother District Council

Project Support

Project Volunteers:

We would like to say a huge thank you for the time and support from our wonderful team of volunteers who collected all of the field data for the 300 plots! This project would not have been possible without your commitment.

Finally, we wish to thank all landowners and members of the public who allowed access to their properties for the collection of the crucial field data.

The Authors & Reviewers

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Executive Summary

- Bexhill has approximately 228,000 trees.

- Bexhill's tree cover stands at an estimated 16% and shrub cover at 6%, giving a total canopy cover of 22% covering an area of over 750 hectares!

- A total of 81 different tree species were recorded in Bexhill as part of the study.

- Of the 81 species, the most common are *Quercus robur* (Oak) with an estimated 43,000 trees, *Fraxinus excelsior* (Ash) with an estimated 20,000 trees, and *Ilex aquifolium* (Holly) with an estimated 18,000 trees.

- Bexhill's urban forest performs well in terms of its structure, with a wide variety of species. There is some dominance of *Quercus robur* (Oak) at species level. It is recommended that future planting focusses on further diversifying the urban forest to reduce reliance on key species like *Quercus robur (O*ak) and improve overall resilience, considering the threat posed by acute oak decline.

- There is a good distribution of both semi-mature and mature trees throughout Bexhill, however there are very few large senescent trees. Managing trees to ensure they reach this large stature is important as generally larger trees result in greater benefit provision. Further planting of young trees should be undertaken to support the ageing population.

- Bexhill's trees and shrubs have the potential to trap and remove over 53 tonnes of air pollution annually at a value of nearly £1.5 million.

- Bexhill's trees reduce surface runoff by over 84,000 m^3 per year. This volume is equivalent to 34 Olympic swimming pools of surface runoff being averted every single year, and it is worth an estimated £152,000 in avoided surface runoff treatment costs.

- In total, Bexhill's trees store around 73,000 tonnes of carbon and sequester an additional 2,000 tonnes of carbon annually with associated values of around £66.6 million and £2 million respectively.

- Trees confer many other benefits such as habitat provision, soil conservation and noise reduction which currently cannot be valued, but should be acknowledged.

Figure 1: Birch tree surveyed by one of our volunteers

Contents

Key Definitions

Urban forest: The trees in and around our urban areas (together with woodlands, shrubs, hedges, open grass, green space and wetland) are collectively known as the 'urban forest'.

i-Tree Eco: a software application which quantifies the structure and environmental effects of urban trees and calculates their value to society. It was developed as the urban forest effects (UFORE) model in the 1990's to assess impacts of trees on air quality and has since become the most complete tool available for analysing the urban forest. Eco is widely used to discover, manage, make decisions on and develop strategies concerning trees in urban landscapes.

Natural capital: refers to the elements of the natural environment – such as the trees and shrubs of an urban forest - that provide goods, benefits and services to people, such as clean air, food and opportunities for recreation (Natural Capital Committee, 2014). As the benefits provided by natural capital are often not marketable, they are generally undervalued, and inventories limited. This can lead to poor decision making about the management and maintenance of natural capital.

Ecosystem services: refers to the benefits which trees provide to the surrounding environment and people. This includes a range of benefits, from urban cooling to amenity value. In this report, the ecosystem services measured are carbon storage and sequestration, pollution removal and avoided surface run-off.

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 website 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 reports on previous UK i-Tree Eco studies visit www.treeconomics.co.uk or www.forestresearch.gov.uk/research/i-tree-eco.

Report Scope

This study investigates the structure and composition of Bexhill's urban forest and the benefit delivery. This report provides baseline information which can be used to inform future decision making and strategy. Understanding the structure and composition of the urban forest is vital to its preservation and development, and by showcasing the value of benefits provided by Bexhill's trees, increased awareness can be used to encourage investment in the wider environment.

The assessments presented in this report provide the opportunity to explore several areas of interest including:

- Maintaining and improving current tree cover in Bexhill.
- Identifying areas vulnerable to loss of tree cover (e.g. as a result of pests, diseases) which would benefit from new planting or enhanced protection.

This report can be used by:

- those writing policy
- those involved in strategic planning to build resilience or planning for sustainable development of the town
- those who are interested in local trees for improving their own and others' health, wellbeing and enjoyment across the town
- those interested in the conservation of local nature

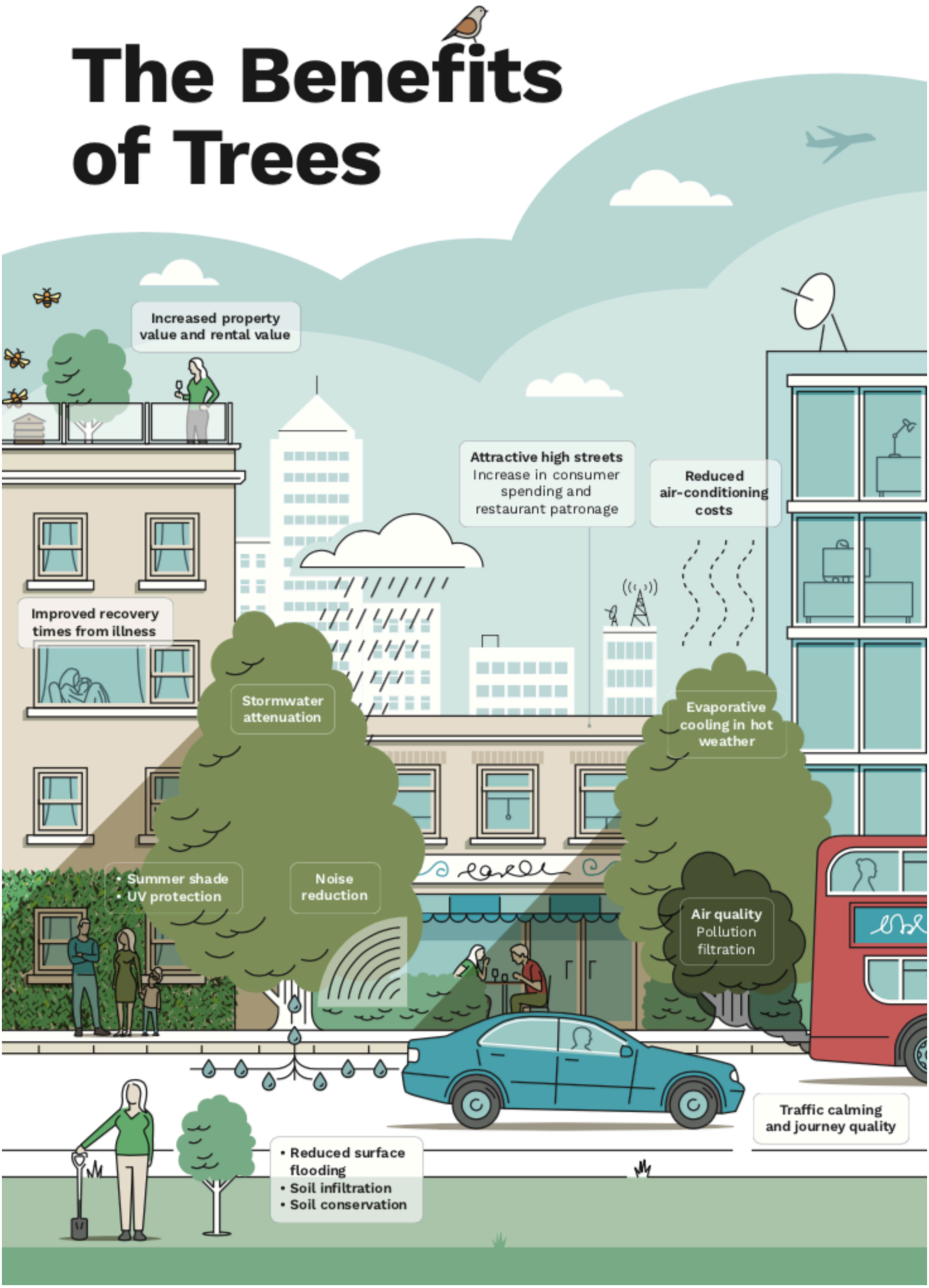
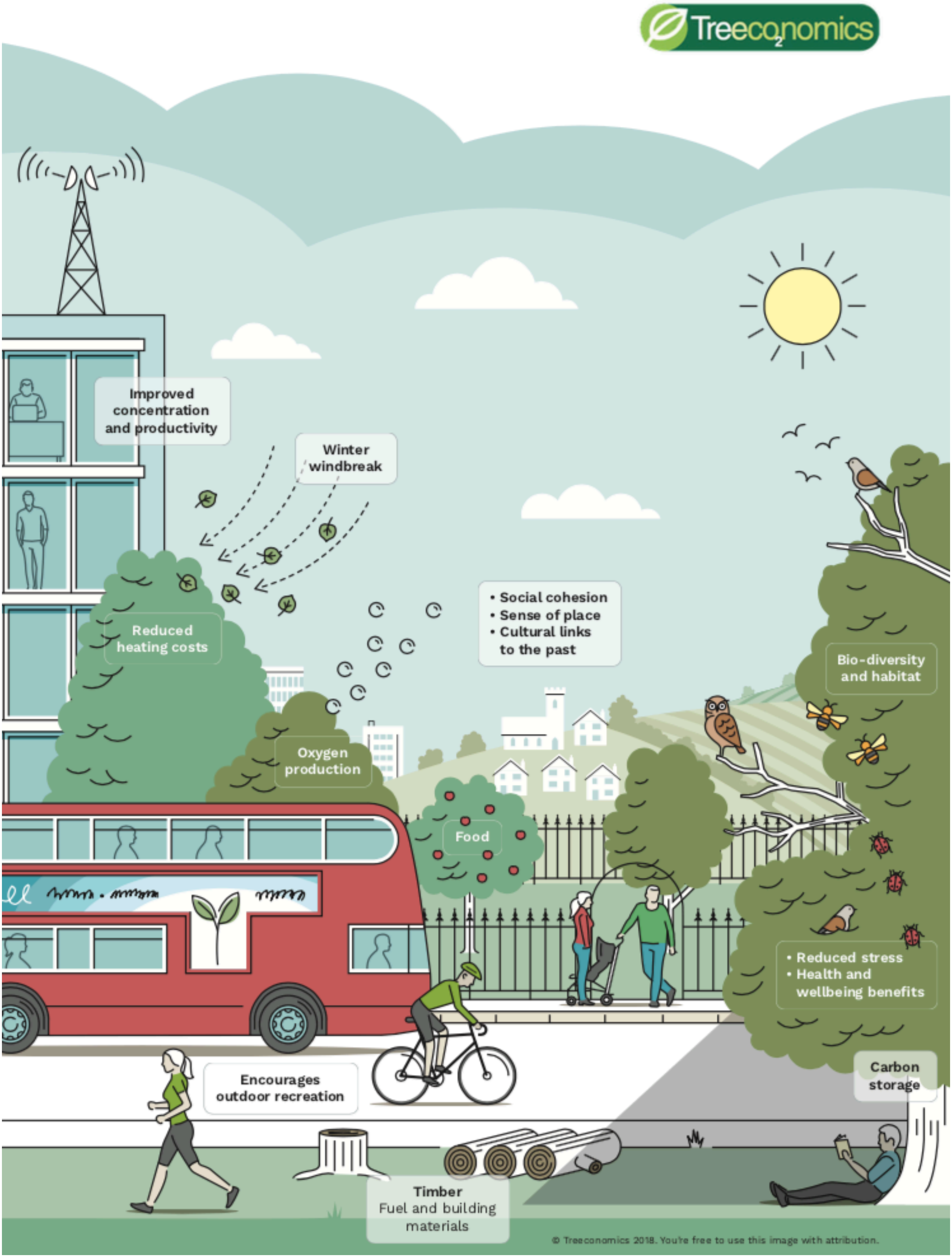


Figure 2: Benefits of Trees Infographic


Treeconomics
Improved concentration and productivity
Winter windbreak
Reduced heating costs
Oxygen production
• Social cohesion
• Sense of place
• Cultural links to the past
Bio-diversity and habitat
Food
• Reduced stress
• Health and wellbeing benefits
Carbon storage
Encourages outdoor recreation
Timber
Fuel and building materials
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Highlights

Structure and Composition Headline Figures	
Number of Trees (estimate)	**228,000**
Average Tree Density (estimate of trees per hectare)	**66**
Tree Cover	**16.1%**
Shrub Cover	**5.5%**
Total Canopy Cover (Tree + Shrub Cover)	**21.6%**
Number of Species Surveyed	**81**
Most Common Tree Species	***Quercus robur, Fraxinus excelsior, Ilex aquifolium***
Proportion of Trees in Good or Excellent Condition	**41.5%**
Proportion of Trees by Diameter at Breast Height (DBH)	**0-15 cm 44.5%** **15-45 cm 45.0%** **45-75 cm 9.7%** **75+ cm 0.7%**
Shannon Weiner Index	**3.4%**
Replacement Cost	**£142.5 million**
Amenity Value of forest in Urban areas (CAVAT)	**£3.28 million**

Ecosystem Services Headline Figures		
Carbon Storage (whole value)	**73,300 Tonnes**	**£66,700,000**
Carbon Sequestration (annual)	**2,160 Tonnes**	**£1,963,447**
Pollution Removal (annual)	**53.0 Tonnes**	**£1,500,000**
Avoided Runoff (annual)	**84,800 m³**	**£152,000**
Total Annual Benefits	**£3,615,447**	

Table 1: Headline Figures

1. Introduction

The Urban Forest & The Benefits of Trees

Trees, shrubs and green infrastructure in the urban realm collectively make up the urban forest[1]. This includes those on public and private land, along streets and waterways, in parks, open spaces and woodlands. Trees in urban areas bring with them both benefits and costs. Whilst many of the costs are well known, the benefits can be difficult to quantify or justify. Nevertheless, a considerable and expanding body of research exists on the benefits that urban trees provide to those who live and work in our urban areas, to green infrastructure and to the wider urban ecosystem. Trees provide a 'sense of place', moderate extremes of high temperature, improve air quality and act as a carbon sink. Yet, trees are often overlooked and undervalued. The benefits of trees are illustrated in Figure 2 'Benefits of Trees Infographic' on Page 8 and those measured in this study are summarised in Table 1 (above).

The Town of Bexhill

Bexhill is located on the South East Coast within the County of East Sussex. Bexhill 'sits at the heart of the of the district of Rother' and is considered a predominantly residential town with a visitor element[2]. Historically, Bexhill was a fishing village which began to grow as coastal resorts became popular and the railway was developed within the Victorian and Edwardian era[3].

The Population of Bexhill

The population of the Rother District in 2010 was 89,987, with 48% (43,531) located in Bexhill[4]. 'Within Bexhill the dominant age group is the 45-64 year olds' which

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[1] Doick, K.J., Davies, H.J., Handley, P., Vaz Monteiro, M., O'Brien, L., Ashwood F., 2016

[2] Storkey, B. and Hazell, A., 2004-2022

[3] Rother District Council, 2009

[4] Rother District Council, 2011

represents 25% of the population, and this age group 'has experienced the greatest percentage growth between 2001 and 2010' of 24.7%. Bexhill has a far greater population density when compared with Rother as a whole according to the Rother's Bexhill town profile. With Life expectancy averaging at 80 years which is slightly above the national and county averages[2].

Deprivation in Bexhill is tending to follow a common downward trend as seen with other coastal areas of the UK where levels of deprivation are increasing alongside unemployment. Sidley ward and Bexhill Central ward are the two main concentrations of poverty in Bexhill and 'parts of which are in the worst 20% of wards nationally'. The county average score stands at 18.78 while Sidley ward has a deprivation score of 34.37. 'Bexhill Central, Eastern Rother, Bexhill Sackville, Rye and Bexhill St Michaels are all in the top quartile (most deprived 75-100%) for the county[2].'

Tourism has been the traditional basis of the local economy although this has been problematic with the decline of tourism, 'low levels of alternative business investment' and the competition for funding with nearby towns Hastings and Eastbourne[2]. Development in Bexhill and Rother more widely depends on the progress of supporting infrastructure with consideration to the strategic gaps between settlements in the district in an effort to retain distinct identity. The gaps between settlements are seen as valuable 'green lungs' between towns[5].

The Natural Environment of Bexhill

Bexhill has a tree cover of 16.1% which is inline with the tree cover average for England of 16%[6]. The current tree cover also exceeds the suggested standard tree cover for coastal towns of 15%[1]. Shrub cover in Bexhill is estimated at 5.5%, when combined with tree cover, this gives a total canopy cover of 22%, which covers an area of 759 hectares.

[5] Rother District Council, 2019

[6] Forest Research, anon

The natural environment in Bexhill-on-Sea, the fringes of Hastings and the rural areas of the Rother district are vitally important to the local environment and to communities and form an integral part of the historical and cultural character. Within the wider rural area surrounding Bexhill, a number of sites are protected with international and national importance including: the High Weald Area of Outstanding Natural Beauty which encompasses the majority of the district outside the urban areas, the Pevensey Levels National Nature Reserve and Ramsar site which border Bexhill, the Dungeness, Romney Marsh and Rye Bay Ramsar site and Rye Harbour Local Nature Reserve which make up part of Rother's coastline. Additionally there are sites with other types of environmental protection on the land and coastline throughout the district such as Sites of Special Scientific Interest, Local Wildlife Sites, Special Areas of Conservation, Ancient Woodland and Priority Habitats and Species[3].

The Future of Bexhill

Looking to the future, a Climate Emergency was declared by Rother District Council in 2019 with a pledge to become carbon neutral by 2030. The urban forest of Bexhill can play a significant role in mitigating impacts related to the climate emergency and meeting targets set out in Rother's Environment Strategy adopted in 2020. Through this study and the subsequent Tree Planting Strategy, significant progress could be made towards achieving a number of the key priorities through having a clear understanding of the existing urban forest structure and quantifying the benefits it provides.

Strategic Priority 3 - 'Air Quality and Sustainable Transport' aims to reduce emissions through encouraging use of public transport and other sustainable transport options such as cycling, increase accessibility to charging points for electric car users, reduce light and noise pollution. Trees can help to improve air quality in urban areas through filtering and trapping airborne pollutants. They also create 'welcoming, attractive and distinctive places' which in turn encourages sustainable transport options such as walking and cycling[7].

Strategic Priority 6 - 'Protecting and Enhancing Biodiversity' highlights the value of trees in the landscape and the benefits they provide to the local urban and rural environment, the community and wildlife and Biodiversity. The Priority aims to double tree cover, increase community engagement through tree planting, reduce flood risk, and protect and enhance key habitats (particularly those which support pollinators).

Strategic Priority 7 - 'Construction and Existing Buildings' anticipates the increasing need for more housing in the near future. One of the key goals of this Priority is to 'ensure a focus on green spaces and tree planting for all new build schemes' and to consider funding which would enable the development of cycling and walking infrastructure.

The Aims of the Bexhill i-Tree Eco Project

1. Illustrate the structure of Bexhill's urban forest, including the species composition, diversity, and tree condition.
2. Calculate the ecosystem service values provided by Bexhill's urban forest and rank the importance of different trees in terms of ES provision using the i-Tree Eco software suite.
3. Promote Bexhill's urban forest to all, and emphasise the benefits it provides.
4. Establish values that are a precursor to proper asset and risk management.
5. Conduct a risk analysis of the susceptibility of Bexhill's urban forest to pests and diseases.

[7] Trees and Design Actions Group, 2021

2. Methodology

To gather a collective representation of Bexhill's urban forest across both public and privately owned land, an i-Tree Eco (v6.0) plot-based assessment was undertaken. The survey focussed on three different project areas as shown in Figure 3 (below), these included; the 'Urban Area' (the area within the current development boundary), the 'Wider Rural Area' (the parish boundary) and the 'Combe Valley Countryside Park'.

300 randomly allocated plots of 0.04ha (400m^2) were distributed throughout the whole project area, equating to 1 plot every 11 ha. Of those 300 plots, 150 were distributed within the 'Urban Area' which can be seen in Figure 4 (below), 100 within the 'Rural Area' and 50 within the 'Combe Valley Countryside Park'.

Figure 3: Project Strata Areas

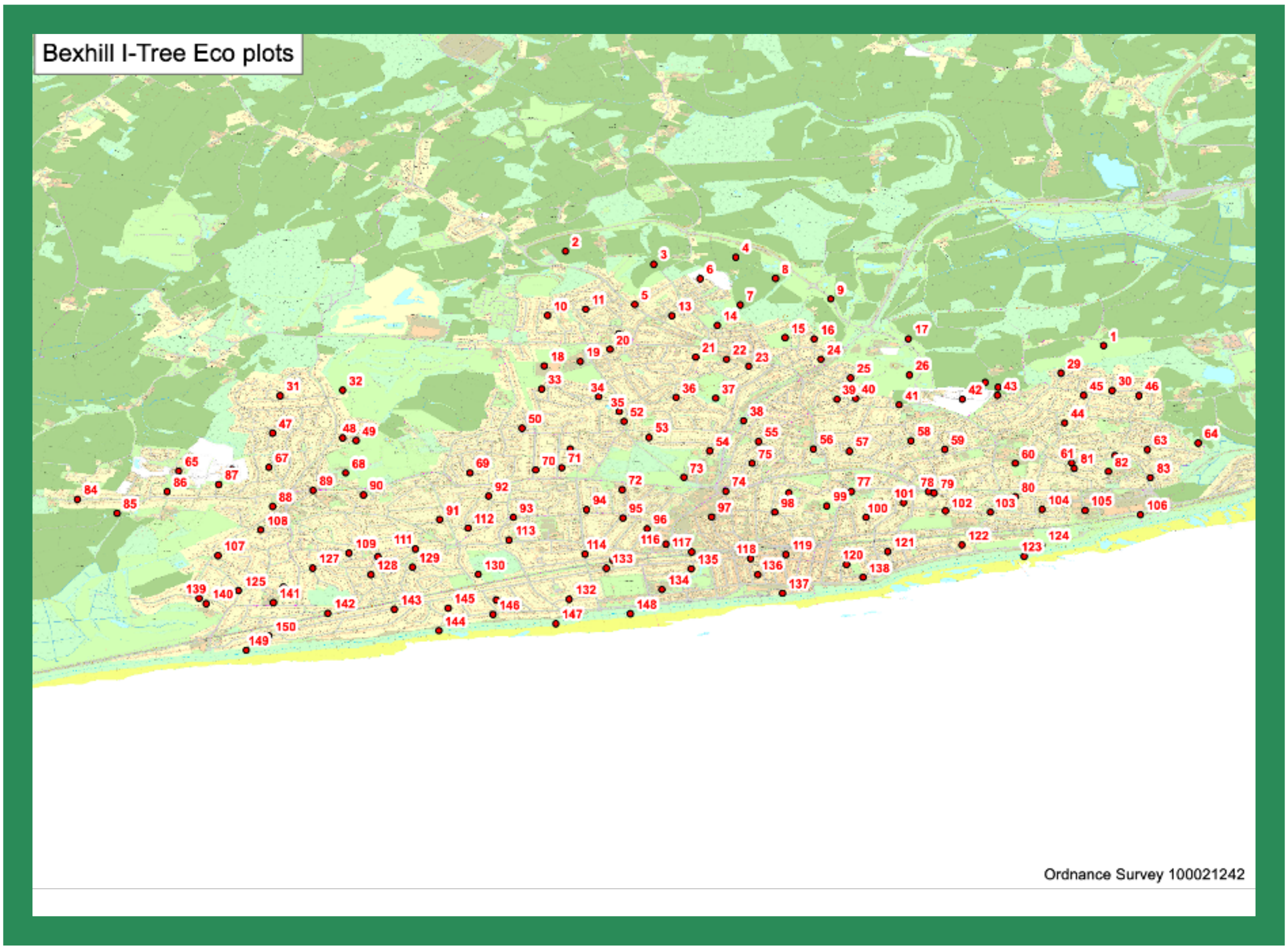

FIgure 4. Sample Plot Distribution Across the Urban Study Area

For comparison with other i-Tree Eco studies, please see Table 2 (overleaf). Random plot selection is generally used where it would not be realistic or practical to survey each individual tree, such as when the study area encompasses a whole town, city, or county. As part of the process data is collected from a number of randomly distributed plots throughout the study area, rather than data collected for each individual tree[8]. The data collected for each of the plots is extrapolated to represent the whole of the study area.

[8] i-Tree Tools, 2020

Study Location	Plot Density
Petersfield	1 plot per 2.7 ha
Bexhill	**1 plot per 11 ha**
Cambridge	1 plot per 20.0 ha
Torbay	1 plot per 26.0 ha
Plymouth	1 plot per 28.5 ha
Belfast	1 plot per 43 ha
Inner London	1 plot per 155.0 ha
Outer London	1 plot per 245.0 ha

Table 2: Comparison of plot density for a range of study locations.

The following information was recorded by surveyors for each plot:

Plot Characteristics

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

Tree Characteristics

Tree species, height (m), trunk diameter at breast height (DBH), canopy spread, the health and fullness of the canopy, light exposure to the crown, distance and direction to the nearest building and safe useful life expectancy (LE).

Shrub Characteristics

Shrub species (if known), height (m), % missing and % of total shrub area.

The data was collected by volunteer surveyors during the summer months of 2021. 300 plots were created for the project and training and back up plots were available additionally.

With plots randomly allocated to ensure a statistically significant distribution across Bexhill, they fall on both public and private land. While most areas could be accessed with permission, some could not. In the event that the plot landed in an area that was inaccessible, a back-up plot was used. This was an additional randomly allocated plot within the same grid square as the original which allowed the full number of 300 plots to be surveyed.

All 300 plots were successfully surveyed by volunteers and/or for some non-treed plots, a GIS analysis of aerial imagery was used. The full methodology for the GIS desktop analysis can be found within the appendices of this report.

Data Limitations

While Bexhill's trees provide a plethora of benefits, the figures presented in this study represent only a portion of the total value of the Bexhill's trees. i-Tree Eco does not quantify all of the services that trees provide; such as moderating local air temperatures, reducing noise pollution, improving health and well-being, providing wildlife habitat and, even, their ability to unite communities. Hence, the value of the ecosystem services provided in this report are considered conservative estimates. Furthermore, the methodology has been devised to provide a statistically reliable representation of Bexhill's urban forest in 2021. This report is concerned with the trees and shrubs within Bexhill. This report should be used only for generalised information on the urban forest structure, function, and value. Where detailed information for a specific area (such as an individual park, street or ward) is required, further detailed survey work should be carried out.

	Reference Values & Methodology Notes for Calculations
Number of Trees	The sample inventory figures are estimated by extrapolation from the sample plots. For further details see the methodology section below.
Total Canopy Cover	The area of ground covered by the leaves of trees and shrubs when viewed from above (not to be confused with leaf area which is the total surface area of leaves).
Capital Asset Value for Amenity Trees (CAVAT)	A valuation method with a similar basis to the CTLA Trunk Formula Method, but one developed in the UK to express a tree's relative contribution to public amenity and its prominence in the urban landscape.
Replacement Cost	The cost of having to replace a tree with a similar tree using the Council of Tree and Landscape Appraisers (CTLA) Methodology guidance from the Royal Institute of Chartered Surveyors.
Carbon Storage	The amount of carbon bound up in the above- ground and below-ground parts of woody vegetation.
Carbon Sequestration	The annual removal of carbon dioxide from the air by plants. Carbon storage and carbon sequestration values are calculated based on BEIS figures of £248 per Tonne for 2022.
Pollution Removal	This value is calculated based on the UK social damage costs for 'Transport Urban Medium' and the US externality prices where UK figures are not available; £0.96 per kg (carbon monoxide - USEC), £0.46 per kg (ozone - USEC), £9.211 per kg (nitrogen dioxide - UKSDC), £6.926 per kg (sulphur dioxide - UKSDC), £168.587 per kg (particulate matter less than 2.5 microns - UKSDC). Values calculated using an exchange rate of $0.75 = £1.00.
Avoided Runoff	Based on the amount of water held in the tree canopy and re-evaporated after the rainfall event. The value is based on an average volumetric charge of £1.796 per cubic metre and includes the cost of avoided energy and associated greenhouse gas emissions. Costed as per Northern Ireland Water charges for surface water and sewerage 2021/22 figures; https://www.niwater.com/sitefiles/resources/news/2021/march/niwsummaryofchargesleaflet21_22.pdf
Total Annual Benefits	Sum of the monetary values of carbon sequestration, pollution removal and avoided runoff. Carbon storage is not included since it is not an annual benefit, but rather an ecosystem service that has already been done and accumulated over time.

Table 3: Calculations Summary

Data was processed using iTree Eco Version 6.0.21.

3. Results

This chapter presents the results of Bexhill's i-Tree Eco survey. Where comparisons of results are made, these are drawn from previous UK i-Tree Eco study reports including:

	Bexhill	Torbay	Cambridge	Newport	London
Units of canopy cover (ha)	745	765	540	582	22,326
Plot Density	1 per 11 ha	1 per 26 ha	1 per 20 ha	1 per 24 ha	1 per 221 ha
Carbon Storage per unit of canopy	98 tonnes	128 tonnes	163 tonnes	130 tonnes	106 tonnes
Carbon Sequestrat-ion per unit of canopy	2.9 tonnes	4.3 tonnes	3.8 tonnes	3.6 tonnes	3.5 tonnes
Pollution Removal per unit of canopy	71 Kilograms	65 Kilograms	119 Kilograms	130 Kilograms	100 Kilograms
Avoided Runoff per unit of canopy	114 m^3	-	181 m^3	151 m^3	153 m^3

Table 4: Outputs from Bexhill's i-Tree Eco Study compared with four other urban areas

3.1 Structure and Composition

Understanding the structure and composition of the urban forest allows for information-based decisions to be made. Within this chapter we will illustrate the current diversity of Bexhill's urban forest and its ability to be resilient to changes in the future including both climate change and pests and diseases. The structure of the urban forest is vital to maintaining and enhancing biodiversity within cities. Diverse forests provide habitats for a greater range of insects, birds, mammals, and other creatures. It also promotes healthier soil, populations and landscapes, less at risk from pests and disease[9]. For these reasons, biodiversity is a major focus of many polices at international and national level, and encouraging biodiversity net gain in urban development is becoming an increasing priority.

Figure 5: Combe Valley Countryside Park

[9] Kendal (2014)

Policy Context

The 2030 Agenda for Sustainable Development, is an action plan with the aim of achieving global sustainability by encouraging member states to further progress the economic, social, and environmental aspects of sustainable development. It outlines 17 sustainable development goals (SDGs) and urban forests can contribute directly to meeting at least 9 (see section 7 for further details). SDG-11 aims to make cities "inclusive, safe, resilient and sustainable", and urban greening can impact these areas significantly. SDG-15 aims to protect life on land with a focus on biodiversity, afforestation, and climate resilience therefore cultivating a healthy and diverse urban forest is vital to cities like Belfast. This includes not just species and size diversity, but a greater evenness of green infrastructure across the city to provide environmental equality[10].

The EU Biodiversity Strategy for 2030 builds on key aspects of the UN Post-2020 Global Biodiversity Strategy and the Sustainable Development Goals. Though the UK is no longer part of the EU, policies like this continue to shape our national frameworks. Green infrastructure is identified as a key component, and it includes a call on European cities of at least 20,000 inhabitants to develop ambitious Urban Greening Plans by the end of 2021. The EU Strategy on Green Infrastructure adopted in 2013 is closely linked to the Biodiversity Strategy, calling for healthy green infrastructure to be developed, preserved and enhanced[11].

It has also been argued that more diverse forests and woodlands are more attractive, particularly when regarded in cities, thereby being of more value to the people. The UK's 25-Year Environmental Plan identifies the need to recover nature and enhance the beauty of landscapes[12]. The Environmental Land Management Scheme has a chapter dedicated to the urban forest and identifies biodiversity as one of six vital 'public goods'[13].The Tree Health Resilience Strategy (2018) aims to protect trees from pests and disease. It emphasises working closely with industry and science to prioritise biosecurity. The goals include: a continued extent of trees; enhanced habitat connectivity, increased genetic and structural diversity, and the encouragement of healthy tree condition[14].

The Environment Strategy for Rother 2020-2030 states an ambitious vision:

"The air will be cleaner as the need to travel will be reduced and those of us that do travel will travel by bike, public transport, electric vehicle, or on foot. The natural and built environment will be enhanced and protected for current and future communities. The Council will be a carbon neutral organisation; the district will be tackling and adapting to climate change. More energy will come from renewable or low-carbon sources, such as solar. Fewer people will live in fuel poverty. Waste will be reduced. The district will be resilient to the impacts of climate change including heatwaves, droughts and flooding. We will each use less water. Everyone will play their role in reducing their impact on the environment."

In the documents following strategy priority pledges there is a commitment to deliver the vision of a greener, more sustainable district by promoting a high quality environment which will maximise the opportunities to improve energy efficiency, biodiversity and resilience.

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[10] United Nations, 2015

[11] European Commission, 2020

[12] HM Government, 2018

[13] gov.uk, 2021

[14] Department for Environment, Food and Rural Affairs, 2018

3.1.1 Ground Cover

Approximately 55% of the ground cover across Bexhill (as measured using i-Tree Eco) was classed as permeable ‘green space’ which includes ground covers such as grass and soil. Apart from a very small percentage (2.5%) of water, the remaining ground cover is made up of non-permeable surfaces such as brick, asphalt and concrete. These ‘hard’ surfaces absorb heat and contribute to a general warming of the urban environment.

The top three ground covers in the ‘urban’ strata are Grass 29%, Tarmac 25% and Building 18%.
The top three ground covers in the ‘parish’ strata are Grass 50%, Unmaintained 21% and Mulch 11%.

Tree cover and shrub cover in the ‘urban’ strata stand at 13% and 7% respectively.
Tree and shrub cover in the ‘parish’ stand at 19% and 5% respectively.

Plantable space in the ‘urban' strata stands at 29%.
Plantable space in the ‘parish’ strata stands at 69%.

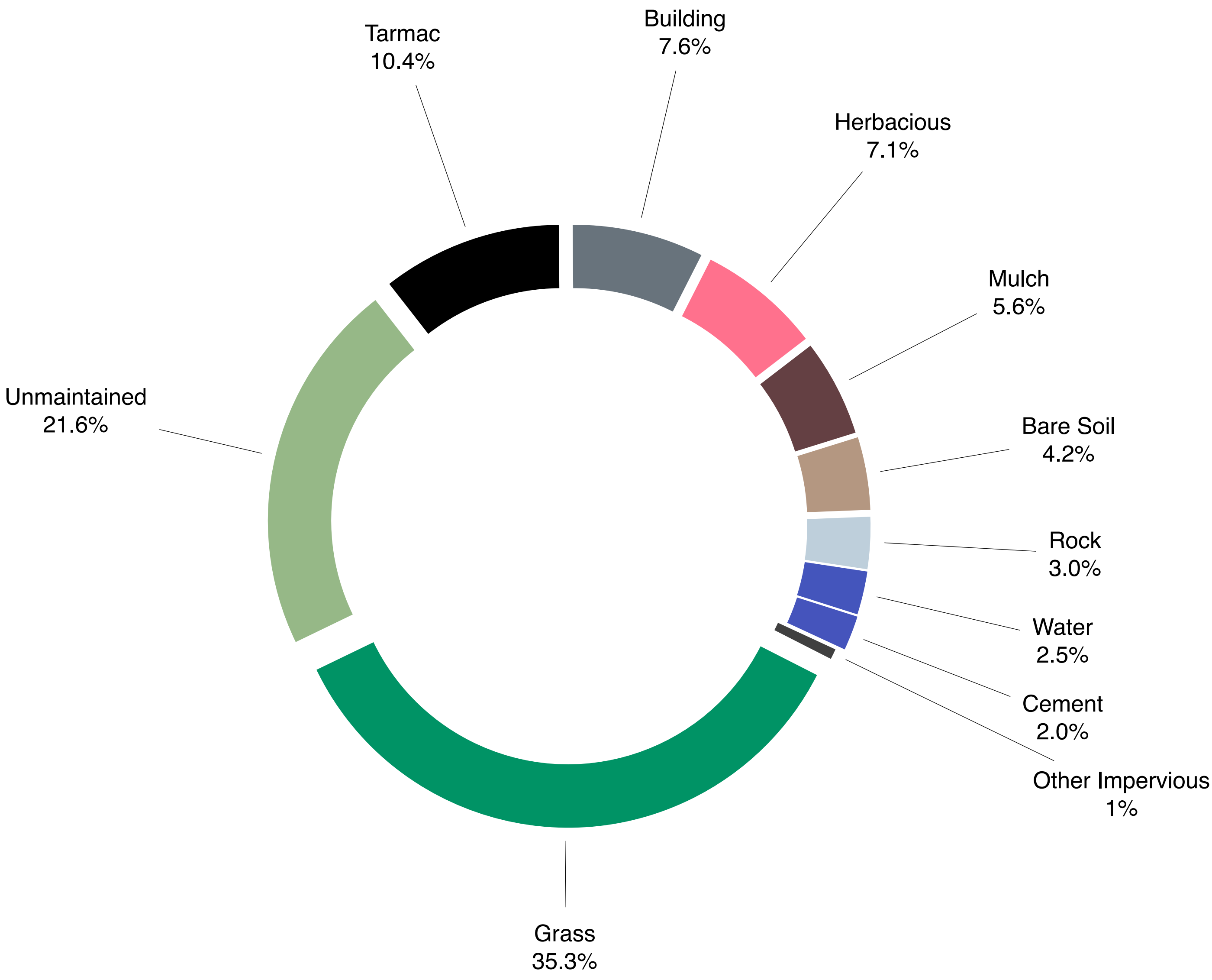

Figure 6: Percentage Ground Cover across Bexhill estimated by Eco

3.1.2 Land Use

The surveyed plots indicate that throughout Bexhill over 21.2% of land is residential (‘*Freestanding structures serving one to four families each*’)[15] with an additional 1.4% multi-family residential (‘*Structures containing more than four residential units*’) [referred to as MF residential throughout].

Within the ‘urban’ strata of Bexhill around 60.2% of land is used for residential purposes, with an additional 3.1% MF Residential. The top three land uses in the 'urban' strata are residential 60%, transportation 15% and agriculture 5%.

In comparison, in the ‘parish’ strata of Bexhill less than 2% of land is residential, this is balanced by the agricultural make up of land in the 'parish' strata which is estimated at 77.0%. The top three land uses in the 'parish' strata are agriculture 77%, golf course 7% and wetland 3%.

[15] i-Tree Tools, Anon

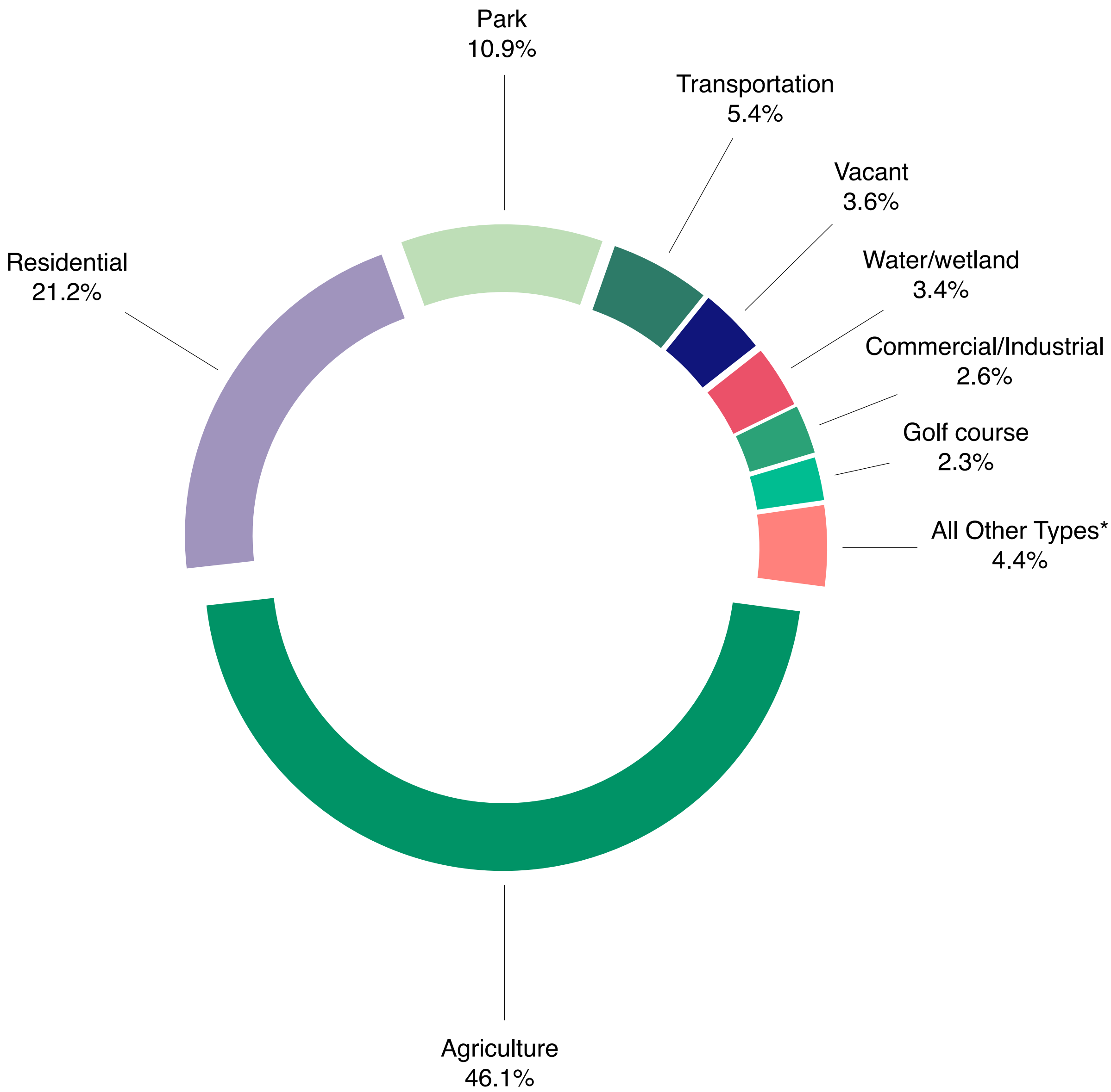

Figure 7: Percentage Land Use across Bexhill estimated by Eco

*’All Other Types' includes land-use categories representing <2% of the total; Institutional: 1.8%; MF Residential: 1.4%; Cemetery: 0.7%; Utility: 0.4% and Other: 0.1%

3.1.3 Tree Species and Diversity

A diverse urban forest is vital to a healthy and resilient environment. It reduces the risk posed by pests and disease and will be better set to deal with future climate change, and is considered by many to be more attractive than a less diverse setting.

This Eco Sample survey of Bexhill's urban forest identified 81 species in total, the wide range of species provides a strong foundation for future urban greening and development. The Shannon Wiener Index provides a diversity score where 1.5 is considered low and 3.5 is considered high. The score takes account of two key concepts in diversity: Richness - the number of species and Evenness - how equally they are represented. The higher the number, the greater the diversity.

The associated diversity index score stands at 3.4 for the whole of Bexhill, with 3.4 in the 'urban' strata and 2.7 in the 'parish' strata.

Towns and cities generally have a greater diversity of species and are therefore often more resilient to environmental changes such as climate change and pest and disease outbreaks than their countryside/rural counterparts[16] which tend to have a greater number of native species and a more uniform species mix[17].

As quoted by many researchers of Urban Forestry, tree diversity is a priority for towns and cities to protect against the ever-present threats posed by climate change and pest and disease outbreaks[18] and to '*ensure long-term provision of benefits*'[19][20]. With a greater range of species, the delivery of benefit quality by trees increases[21].

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[16] Morgenroth *et al*., 2016

[17] Morgenroth *et al*., 2016, McKinney, 2006

[18] Santamour, 1999; Morgenroth *et al.*, 2016; Kendal 2014

[19] Morgenroth *et* al., 2016; McKinney, 2006

[20] Morgenroth *et al*., 2016

[21] McKinney, 2006

Figure 8 (below) shows the top ten tree species according to their proportion of the total tree population within Bexhill.

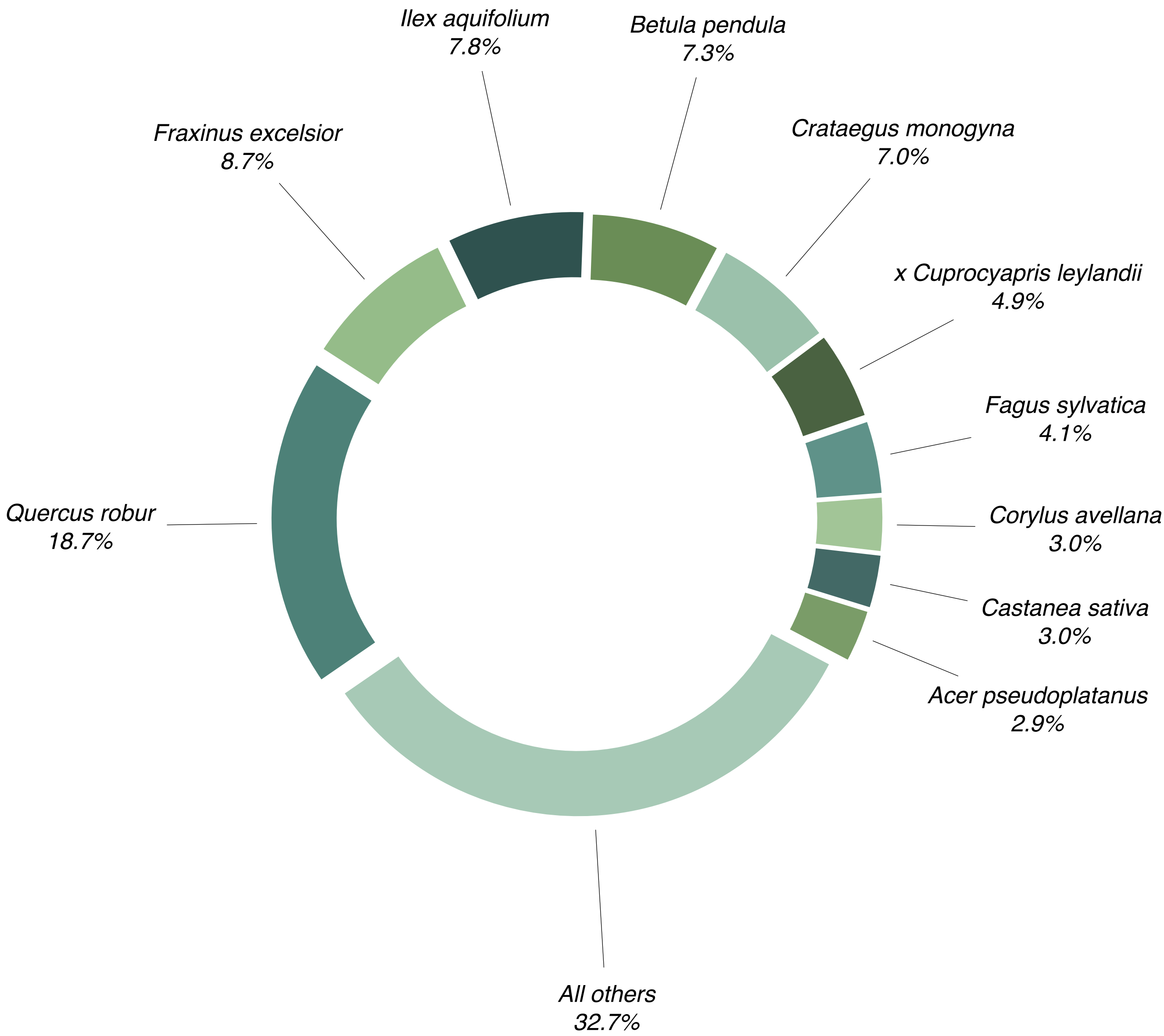

Figure 8: Percentage Population of the top ten Tree Species across Bexhill

The most common tree species is *Quercus robur* (Oak) which represents 19% of the trees in Bexhill's urban forest. The second and third most common species are *Fraxinus excelsior* (Ash) representing 9% and *Ilex aquifolium* (Holly) representing 8% of Bexhill's urban forest.

The 'urban' strata is made up of 67 species. The three most common species are *x Cuprocyapris leylandii* (Leyland cypress) 17%, *Quercus robur* (Oak) 13% and *Ilex aquifolium* (Holly) 5%. They collectively make up 34% of the 'urban' strata's 67,828 trees.

The 'parish' strata is made up of 27 species. The three most common species are *Quercus robur* (Oak) 22%, *Betula pendula* (Silver birch) 11% and *Ilex aquifolium* (Holly) 10%. They collectively make up 44% of the 'parish' strata's 124,487 trees.

Santamour's 10-20-30[22] rule may be considered a useful tool in planning for maintaining diversity of species; the 10-20-30 rule is applied by some urban foresters as a rough guide to maintain a diverse population. This 'rule' suggests that no single species should represent more than 10% of any population, no single genus should represent more than 20% of a population and no single family should represent more than 30% of a population. This practice has been discussed by other authors such as Kendal[23] and Sjöman,[24] who have further examined the evidence and practicality. In future it may also be useful to consider further diversifying the population towards meeting Barker's 1975 benchmark of 5% per species.[25]

In Bexhill, the most common species, *Quercus robur* (Oak) is the only species that represents over 10% of the population standing at 19%. Though species diversity is high with 81 species, 60 of these species each represent less than one percent of the urban forest population. As a result, a more even species distribution would help to make the urban forest more balanced and resilient. Appendix II contains a full list of species.

Species which originate from more distant regions to each other may be more genetically dissimilar and their presence may therefore increase resilience to environmental perturbations. Tree species represented in Bexhill's urban forest inventory are primarily from three continents. Most of the species are native to Europe and Asia (see Figure 9 below). However, further work would be required to assess the condition, size and populations of these trees and to provide recommendations on the best species to choose for any future plantings.

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[22] Santamour, 1999

[23] Kendal, 2014

[24] Sjöman *et al*, 2012

[25] Barker, 1975

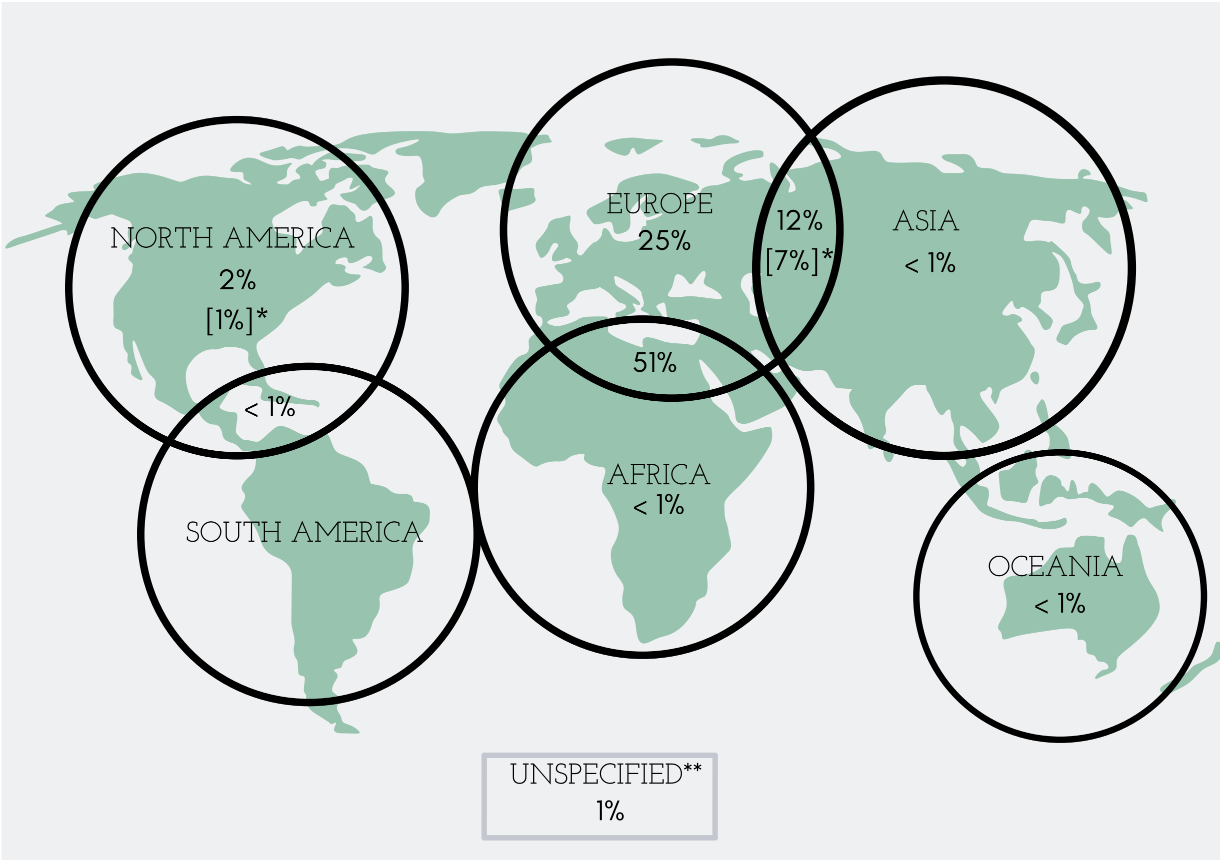

Figure 9: Origin of Tree Species: Share of trees native to different geographical regions. Overlaps indicate origins within both continents

*In these cases the proportion in brackets may include additional regions.
**Whilst there are still a few species whose origin remains unknown, most of these are hybrid *species* with a likely parentage from two zones rendering the concept of regional origin mute.

3.1.4 Leaf Area and Dominance

Leaf area is an important metric because the total surface area of a tree canopy is directly related to the amount of benefit provided. Generally the larger the canopy and its surface area, the greater the amount of air pollution or rainfall which can be held in the canopy of the tree.

Within Bexhill's urban forest, total leaf area is estimated at 8,900 ha. If all the leaves within these tree canopies were spread out, they would cover an area over 15 times the size of the Combe Valley Countryside Park in Bexhill (which is approximately 583 ha)!

The most dominant species in terms of leaf area is Quercus *robur* (Oak) accounting for 32.2% of the total leaf area. Followed by *Fagus sylvatica* (Beech) and *Castanea sativa* (Sweet chestnut) which have the second and third largest leaf areas, with 10.1% and 8.4% respectively. Figure 10 (below) shows the top ten most dominant trees' contributions to leaf area. In total these ten species, representing 57.6% of the tree population, contribute over 78.1% of the total leaf area.

The 'urban' strata contributes 22.9% of the total leaf area for Bexhill covering an area of 823 hectares.

The 'parish' strata contributes 61.8% of the total leaf area for Bexhill covering an area of 2,220 hectares.

Leaf area varies greatly between tree genera and species, depending on the size, shape and structure of both the individual leaves and the tree as a whole. Both *Quercus robur* (Oak) and *Fagus sylvatica* (Beech) trees are good in this regard, and this is reflected in Oak providing 32.2% of the total leaf area and beech providing 10.1% of the total leaf area in Bexhill, despite only accounting for 18.7% and 4.1% of the total tree population respectively.

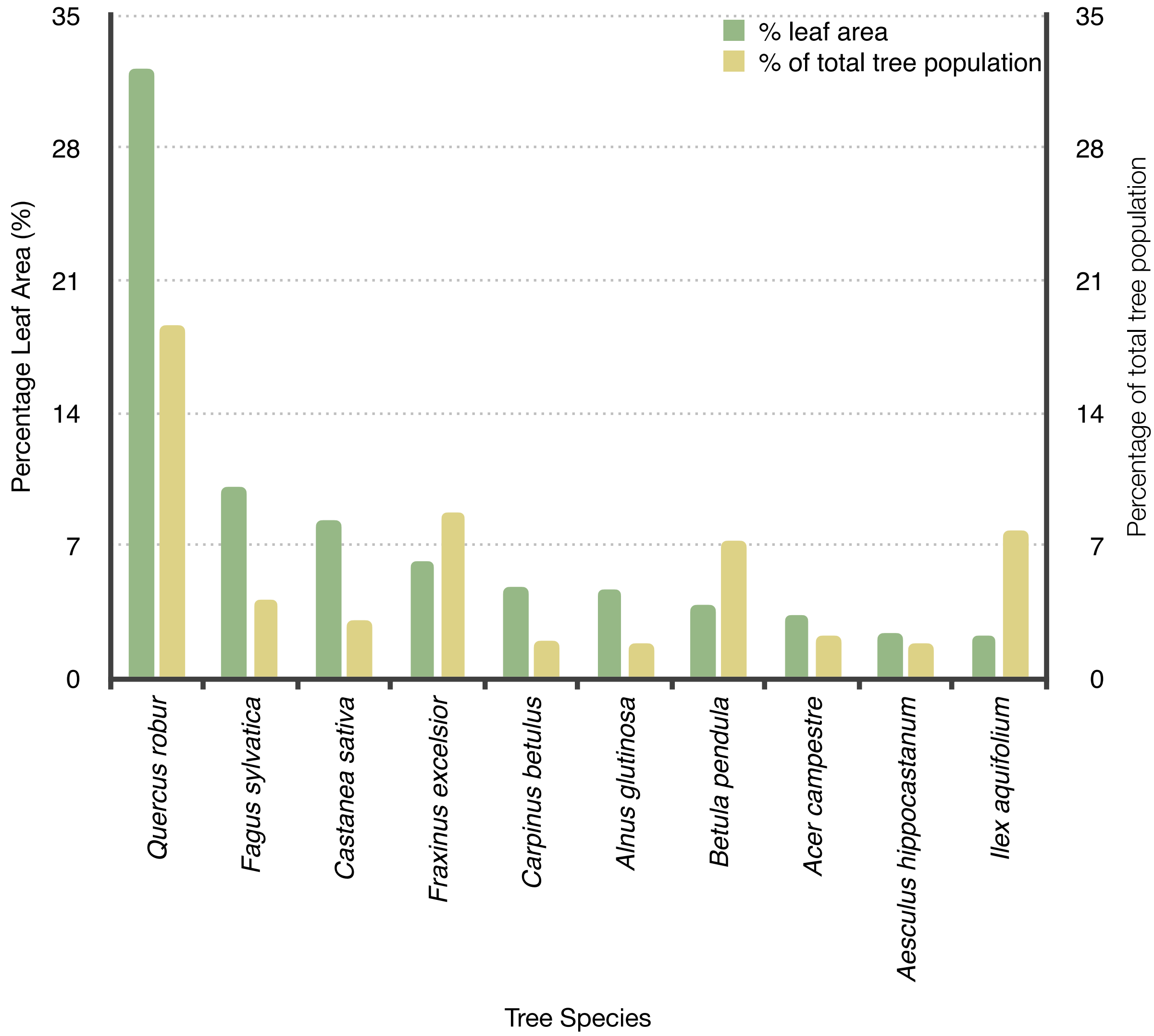

Figure 10: Percentage Leaf Area and Population of the Ten Tree Species With the Highest Leaf Area

3.1.5 Size Distribution

Size class distribution is also an important aspect to consider in managing a sustainable and diverse tree population, as this helps ensure that there are enough young trees to replace those older specimens that are eventually lost through old age or disease. It is also relevant in terms of benefit delivery, as generally larger trees deliver greater benefits.

In Bexhill's urban forest, trees were sized by diameter at breast height (DBH). Figure 9 (below) shows the percentage of the tree population for the ten most common tree species by DBH class. The chart represents a typical size class distribution for an urban area with percentage composition declining as size increases. There is, however, some variation between species. If new plantings are made up of smaller stature species there will be a lack of larger trees in the future. To maintain or increase canopy cover and tree benefits at or above current levels, more trees capable of attaining larger statures will need to be planted and maintained.

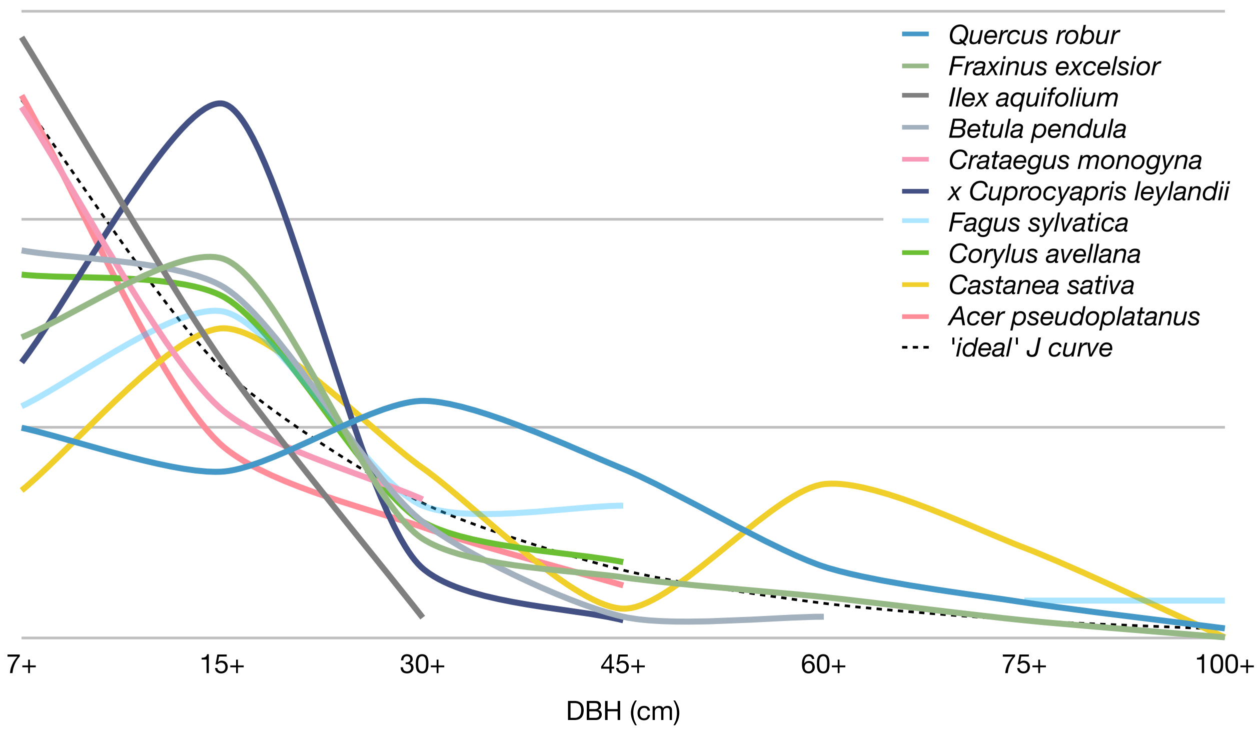

Figure 11: Spread of size classes amongst the top ten species, showing comparison to 'ideal' J-curve
'ideal' J-curve values reduce by half for each increase in DBH class

3.1.6 Replacement Cost

In addition to estimating environmental benefits provided by trees, Eco also provides a structural valuation. In the UK this is termed the 'Replacement Cost'. It must be stressed that the way in which this value is calculated means that it does not constitute a benefit provided by the trees. The valuation is a depreciated replacement cost, based on the Council of Tree and Landscape Appraisers (CTLA) formulae.[26]

Replacement Cost is intended to provide a useful management tool, as it is able to value what it might cost to replace any or all of the trees (taking account of species suitability, depreciation and other economic considerations) should they become damaged or diseased for instance. The replacement costs for the ten most valuable tree species across Bexhill's urban forest are shown in Figure 12 (below).

The total value of all trees in the study area, as estimated by Eco, currently stands at approximately £142.5 million.

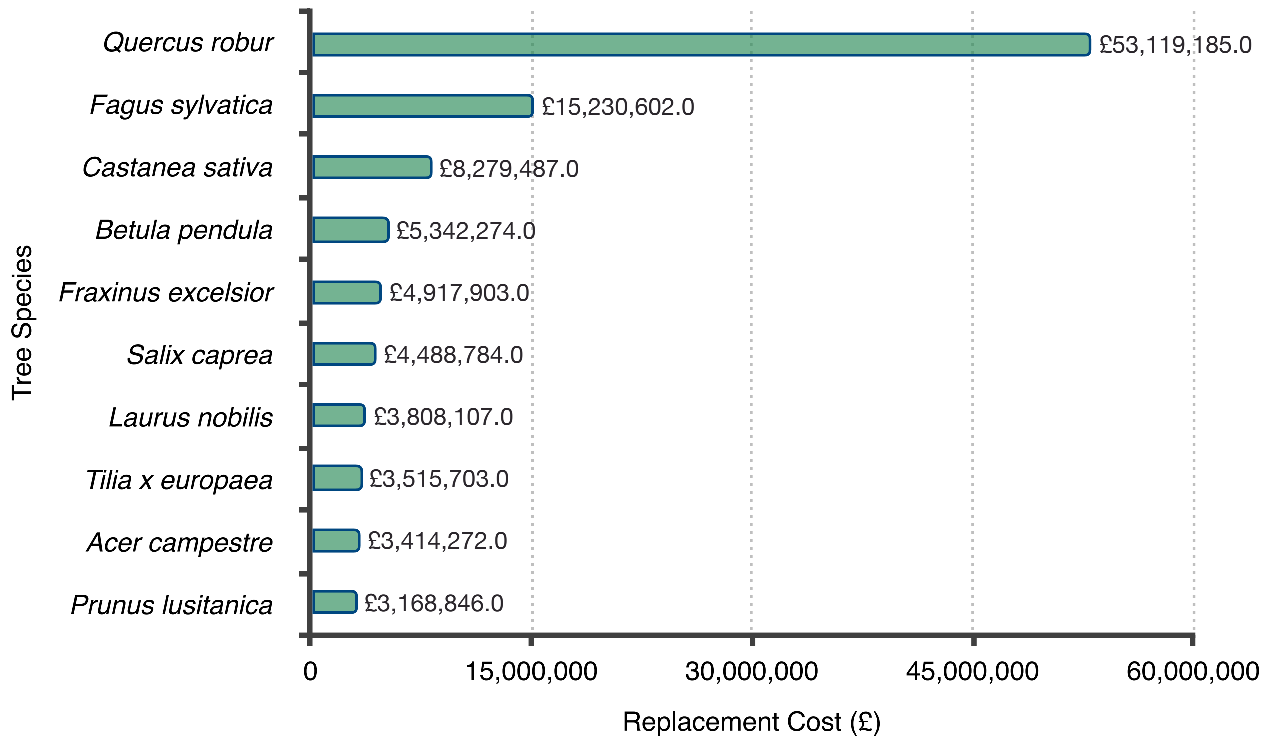

Figure 12: Replacement Cost for Top Ten Tree Species in Bexhill

[26] Hollis, 2007

The population of *Quercus robur* (Oak) trees are the most valuable, followed by *Fagus sylvatica* (Beech) and *Castanea sylvatica* (Sweet chestnut). These three species alone have a replacement cost of **£76.6 million** (54%) of the total replacement cost of the trees in Bexhill's urban forest, with the species *Quercus robur* (Oak) accounting for 37% of the urban forest's total replacement cost at over **£53 million.** A full list of trees with the associated replacement cost is given in Appendix III.

There are an estimated 67,800 trees in the 'urban' strata of Bexhill's urban forest. Making up 29.8% of Bexhill's urban forest tree total. The total replacement cost for these trees according to Eco is over £46.3 million accounting for 32.5% of the total urban forest's replacement cost.

There are an estimated 125,000 trees in the 'parish' strata of Bexhill's urban forest. Making up 54.6% of Bexhill's urban forest tree total. The total replacement cost for these trees according to Eco is just under £82.4 million accounting for 57.8% of the total urban forest's replacement cost.

3.1.7 Potential Pests and Diseases

Pests and diseases can have a serious impact on tree populations and can affect the overall sustainability of the tree resource and the extent of associated ecosystem service delivery. In the UK, there have been significant outbreaks of pests and diseases which have had (and are still having) wide-reaching impacts, such as Dutch Elm Disease and ash Dieback. More recently, tree mortality caused by pathogens such as *Xylella fastidiosa* and damage attributed to pests such as Asian Longhorn Beetle, have become of increasing concern as they continue to spread throughout Europe.

Climate change is expected to increase the threat associated with pests and diseases (Forestry Commission, 2014), as the native ranges of pathogens is altered, and life cycle patterns change. As such, it is important to recognise and understand the potential impact of pests and diseases on our trees. Risk matrices have been developed to determine the probability of establishment of pests and diseases, and the percent of Bexhill's tree population that could be affected, Table 5 and Table 6 (below).

	% of tree population		
Prevalence	0-5%	6–10%	>10%
Not in UK	(green)	(amber)	(amber)
Present in UK	(amber)	(amber)	(red)
Present in South East England	(amber)	(amber)	(red)

Table 5: Risk matrix used for the probability of a pest or disease becoming prevalent in Bexhill's urban forest on a single genus (one or more species).

	% of tree population		
Prevalence	0–25%	26–50%	>50%
Not in UK			
Present in UK			
Present in South East England			

Table 6: Risk matrix used for the probability of a pest or disease becoming prevalent in Bexhill's urban forest on multiple genera.

The impact of some pests and diseases that are already present has also been assessed. The results of this assessment can be found in Table 7, and present the risk to the entire tree resource evaluated as part of this project including the 'urban', 'parish' and, 'countryside park' strata, as well as the population that could be affected and their amenity value. The pests and diseases evaluated have been selected because of the severity of their potential impact on tree health, or because they pose a risk to human health, and is therefore not an exhaustive list of pathogens that could affect the health of Bexhill's trees. The information in table 10 could be used to inform monitoring programmes to ascertain the presence and/or spread of a pest or disease, and the development of strategies to manage the risks that they might post.

Further details on individual pests and diseases can be found in Appendix IV.

Pest/ Pathogen	Species affected	Prevalence in the UK	Prevalence in South-east England	Risk of spreading to Bexhill	Population at risk (%)	CAVAT value of trees (£)
Acute oak decline	A number of oak species, including Quercus robur, Q. petraea, Q. cerris, and Q. ilex. For a full list of species, see Appendix IV.	Central, Eastern and SE England, Welsh borders and SE Wales	Present	Very high	19.0%	£2.1m
Asian longhorn beetle	Many broadleaf species (see Appendix IV)	None (previous outbreaks contained)	None	Medium (climate may be suitable)	50.0%	£437,955
Bronze Birch Borer	All Betula spp.	None	None	Medium (climate may be suitable)	7.8%	£35,989
Chalara dieback of ash	Fraxinus excelsior, F. angustifolia	Throughout England and Wales, SE Scotland and N. Ireland	Present	Already present	8.8%	£83,484
Large eight-toothed bark beetle	Most Picea spp., also reported on some Abies spp., Pinus spp., Larix spp.	Limited outbreaks in SE England	Several outbreaks in Kent and East Sussex	Very high	1.3%	£11,434
Emerald ash borer	F. excelsior, F. angustifolia	None	None	High (suitable climate)	8.8%	£83,484
Xylella fastidiosa subsp. multiplex	Quercus robur, Ulmus glabra, Platanus occidentalis, Q. rubra, Acer pseudoplatanus, Prunus cerasifera	None (one previous interception in the UK)	None	Medium	22.0%	£2.07m
Oak processionary moth	Quercus spp.	Established in Greater London and locally in home counties	Some sites recorded in West Sussex	High	19.1%	£2.1m

Table 7: The risk of a range of pests and diseases becoming prevalent in Bexhill, and the potential impact on its tree resource (Note: CAVAT value provided for urban trees only)

Chalara Dieback of Ash

Chalara dieback of ash, also known simply as Ash Dieback (*Hymenoscyphus fraxineus*) is a major problem currently faced in the UK. A vascular wilt fungus causes the dieback and can often lead to the death of ash trees. Ash Dieback is harmless in its native range in Asia, associating with native ash species including *Fraxinus mandshurica*. However, other *Fraxinus* species, particularly *Fraxinus excelsior*, which is a significant species in Bexhill in regards to tree number, has shown to be highly susceptible to the pathogenicity of *H. fraxineus*. Whilst thought to have been

Figure 13: Hollow Oak, Knole Park

introduced to Europe in 1992, it was first discovered in the UK at a nursery in Buckinghamshire in 2012[27]. It has had a major impact upon the ash population in several countries, and since being found in the UK, the rate of infection has increased at a steady rate and widely present in continental Europe and Ireland. The greatest public risk from Ash Dieback is likely to be found in areas such as highways and trackways. Ash trees on these sites are subject to significant stress factors, such as high salt content in soils due to winter salting, which can increase disease susceptibility.

The risk to the trees in Bexhill is very high. *Fraxinus* accounts for 8.7% of the population (over 19,000 individual trees), species include *Fraxinus excelsior*. *Fraxinus excelsior* is the third highest carbon storing species, the fourth highest carbon sequestering species, and the fourth best at intercepting stormwater and removing pollution from the atmosphere.

They are a significant presence in Bexhill and should be carefully managed to prevent a massive drop in canopy cover and ecosystem service provision over then next decade. The total replacement cost for these trees stands at nearly £5 million.

Acute Oak Decline

Acute oak decline (AOD) mainly affects mature trees (>50 years old) of both native oak species (*Quercus robur* and *Q. petraea)*, but symptoms have also been identified on younger oaks and additional species, including *Q. cerris* and *Q. fabri*. Some affected trees can die in as little as 4-6 years after symptoms have developed. Over the past few years, the reported incidents of stem bleeding and exit holes of the associated beetle *Agrilus bigatatus*, indicating potential AOD infection, have been increasing.

[27] Defra, 2013

The condition appears to be most prevalent in the Midlands and the South East of England, although is spreading west. There are confirmed cases of acute oak decline on the Welsh/English border and in South East Wales.

Oak Processionary Moth (OPM)

OPM (*Thaumetopoea processionea*) was first accidentally introduced to Britain in 2005 and now there are established OPM populations in most of Greater London and in some surrounding counties. It is thought that OPM has been spread through imported nursery trees and it has been estimated that OPM could survive and breed in much of England and Wales.

The caterpillars cause serious defoliation of oak trees, their principal host, which can leave them more vulnerable to other stresses. The caterpillars have urticating (irritating) hairs that can 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 in recent years. Whilst the outbreak in London is beyond eradicating, the rest of the UK maintains its European Union Protected Zone status (PZ) and restrictions on moving oak trees are in place to minimise the risk of further spread.

Selection of pests and diseases for analysis

Individual pests and diseases were not actively identified during the survey work for the project. In assessing the impact of pests and diseases, estimates of tree numbers were compared with the listed susceptible species for each pest or disease. Information was sourced from DEFRA's plant health portal and pests and diseases were selected for assessment based on their level of priority or concern. This included those that can lead to tree death or pose a significant human health risk; further details on individual pests and diseases are provided in the appendix. It is to be noted that this is not an exhaustive list of pests and diseases that may be present or have the potential to affect Bexhill's urban forest should they enter into the UK.

Managing tree health

Bexhill's tree population can be more resilient to the threats of pests and diseases with increased tree species diversity. Through planting and maintaining trees of a wide range of species from a variety of different genera and families the potential impact of some pathogens can be minimised.

Guidance on tree species selection for diversification and in consideration of the changing climate can be found from the Right Trees for a Changing Climate database (http://www.righttrees4cc.org.uk/), and the Trees, Design and Action Group 'Species Selection for Green Infrastructure' (https://www.tdag.org.uk/tree-species-selection-for-green-infrastructure.html).

Regular monitoring can help to maintain an informed picture of the health of the local tree population and instigate a rapid response to get on top of any possible outbreaks before they become a problem. This is particularly important for urban trees, where there is a greater chance that any dieback associated with pests and diseases might affect health and safety.

3.1.8 Conclusions & Recommendations for Structure and Composition

Quercus robur (Oak) makes up the largest proportion of trees in Bexhill, with all *Quercus* species accounting for 43,400 trees (18.7% total population). *Fraxinus excelsior* (Ash) accounts for 8.7% of the tree population, 6.2% of the total leaf area and is the third most dominant species in that regard. Despite Bexhill already having 81 different species, there is room to improve the diversity and dominance and focus on larger stature, longer lived species. Though species diversity is high, more could be done to improve the species distribution to avoid reliance on a single species. The top 10 most common species account for 67.3% of the total tree population.

The tree size distribution is fairly typical of most urban landscapes, indicating that 67% of the top 10 most common trees have a DBH of 7-30cm, and 20% are between 30.5-60cm. Trees with a DBH greater than 90cm were the least common, representing <1% of the total tree population. Larger trees typically provide more ecosystem benefits to the community, and thus the more mature trees must be protected and managed to ensure they thrive and grow to their full potential.

In terms of species selection in relation to pest and disease, new planting should focus on further diversifying species which are currently at risk, and replacing those with the potential to be impacted, for example *Fraxinus excelsior* (Ash).

This study indicates that the tree density across Bexhill is 66 trees/ha, and the tree canopy cover is approximately 16.1%, with a further 5.5% shrub cover.

The pressures associated with urban living can increase trees susceptibility to pests and disease, most notably in those along streets and highways. These trees will require constant management to ensure they remain healthy, and to protect the diversity of the urban forest.

Given these findings, it is recommended that:

1. A wide variety of tree species are planted (with due consideration to local site factors) to increase diversity and reduce any over-reliance on dominant species identified as part of this study. Leading to a more resilient population to our changing climate, and the impacts of pest or disease outbreaks.

2. Protection for existing mature and maturing trees is of great focus, together with increasing the planting of large-stature trees, (where appropriate) to increase canopy cover and the provision of benefits. Targeted planting in areas with low existing canopy cover can help to achieve greater evenness and increase environmental equality.

3. Bexhill should aspire to achieve 20% tree canopy cover by 2050. Part of this goal is achievable through protection and enhancement of existing trees (see 2 above). Further investigation should highlight barriers to the planting and establishment of trees in areas with lower canopy cover.

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

    i. Bexhill carefully plan future tree planting locations and species selection to achieve the recommendations listed above.

    ii. Bexhill continues to communicate and promote the benefits of their urban forest with the community. Online resources such as WebMaps can be a great way to illustrate this information and show distributions.

    iii. Bexhill should produce a strategic Urban Forest Master Plan (with a vision for 2100). This plan should set out how recommendations can be should include criteria for a repeat assessment in 5-7 years to monitor progress.

5. Work to further the engagement of local people through the Tree Warden scheme, and encourage the monitoring and maintenance of newly planted trees by local volunteers to ensure the survival of young trees.

3.2 Ecosystem Service Provision

Trees provide a wide range of services, and urban trees in particular are under significant pressures to perform. Air pollution in cities has been known to cause health problems, excess storm water run-off can cause flooding, and rising populations and increasing density can raise temperatures by up to two degrees Celsius in cities compared to surrounding rural landscapes. Bexhill's trees and green spaces are a critical resource securing a sustainable future for local communities. The ecosystem services provided by trees are at the front line in the fight against climate change.

Policy Context

Urban trees are crucial to making urban living sustainable, and can contribute to meeting global and national targets such as limiting the rise of global temperatures to below 2 degrees Celsius (The Paris Agreement)[28], reaching carbon net neutrality by 2050 (UK Climate Change Act)[29], and cutting greenhouse gas emissions by 68% by 2030 (The UK's Nationally Determined Contribution)[28].

By sequestering and storing carbon, filtering air pollution and reducing surface water run-off, the urban forest contributes significantly to the achievement of the targets within the Sustainable Development Goals, the Kyoto Protocol, the New Urban Agenda, the National Planning Policy Framework, the 25-Year Environmental Plan, the Environmental Land Management Scheme, and many others. These policies and frameworks cover a vast range of issues, namely limiting the effects of climate change by sequestering carbon and reducing temperatures, ensuring the sustainable and efficient management of water resources, protecting people and property from both fluvial and coastal flooding, promoting equality in housing, opportunity, environment and education (amongst others), driving for biodiversity net gain and many more issues besides.

At a local level, Rother has its Environmental Strategy 2020-2030 document which pertains directly to sustainability and the environment within the district. This incorporates the goals of the overarching international and national policies into a vision and strategy based on a commitment to be a carbon neutral district by 2030. It is to be used across different sectors, both public and private, within the district to lay the foundations for developing a detailed plan for delivery of its aims. The urban forest should be recognised to play a significant role as the strategy progresses towards delivery as the urban forest has influence within all of the three policy themes highlighted to provide a framework for the delivery plan. These are 'clean growth', 'healthy places' and 'sustainable services'[30].

[28] United Nations, 2015

[29] legislation.gov.uk, 2008

[30] Rother District Council, 2020

3.2.1 Air Pollution Removal

Poor air quality is a common problem in many urban areas, in particular along transport corridors. Air pollution caused by human activity has caused issues since the beginning of the industrial revolution. With increasing populations and industrialisation, large quantities of pollutants are produced and released into the urban environment. The problems caused by poor air quality are well documented, ranging from severe health problems in humans to damage to buildings.

Urban trees can help improve air quality by reducing air temperature and directly removing pollutants.[31] Trees intercept and absorb airborne pollutants on the leaf surface.[32] Through removing pollution from the atmosphere, trees can reduce the risks of respiratory disease and asthma, thereby contributing to reduced healthcare costs.[33]

Trees emit volatile organic compounds (VOCs) that contribute to ozone formation which is detrimental to human health. However, integrated studies have revealed that an increase in tree cover leads to a general reduction in ozone through a reduction in air temperature. Eco accounts for both reduction of ozone and production of VOCs within its algorithms, Eco estimated that the surveyed trees in Bexhill contribute to a net reduction in ozone concentrations as seen in figure 8 (below).

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[31] Tiwary et al., 2009

[32] Nowak et al., 2000

[33] Lovasi et al., 2008

Across Bexhill it is estimated that the trees and shrubs of the urban forest remove 53 tonnes of pollutants from the atmosphere each year, with an associated value of £1,520,000. This includes nitrogen dioxide (NO_2), ozone (O_3), sulphur dioxide (SO_2) and particulate matter 2.5 µm (PM2.5). Figure 15 (below) shows a breakdown of the pollution removal and the associated values in relation to Bexhill's urban forest.

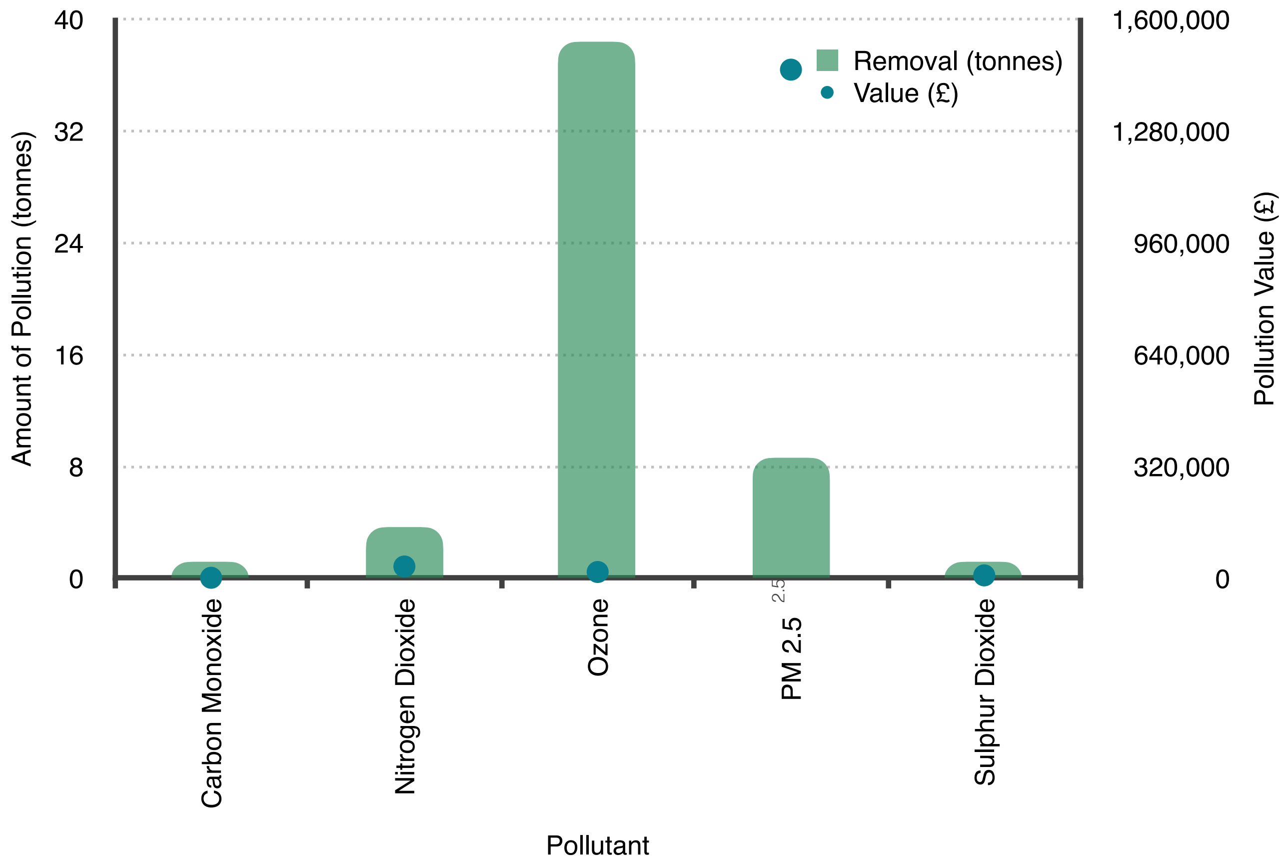

Figure 15: Value of the Pollutants Removed and Quantity Per-Annum

*The valuation method uses, where available, UK social damage costs (UKSDC). Where there are no UK figures, the US externality cost (USEC) is used as a substitution. These US costs were used for Ozone only.

The 'urban' strata makes up 22.9% of Bexhill's total urban forest pollutant removal with 8.9 tonnes removed each year.

The 'parish' strata makes up 61.8% of Bexhill's urban forests total pollutant removal pollutant removal with 23.9 tonnes removed each year.

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

As different species can capture different sizes of particulate matter,[34] it is recommended that a broad range of species should be considered for planting in any air quality strategy. Typically the canopy of deciduous trees have a greater leaf area, however they do loose their leaves during the Autumn and Winter and therefore cannot provide these benefits year round like their evergreen counterparts.

The top three species for pollution removal across Bexhill's urban forest are *Quercus robur* (Oak), *Fagus sylvatica* (Beech) and *Castanea sativa* (Sweet chestnut).

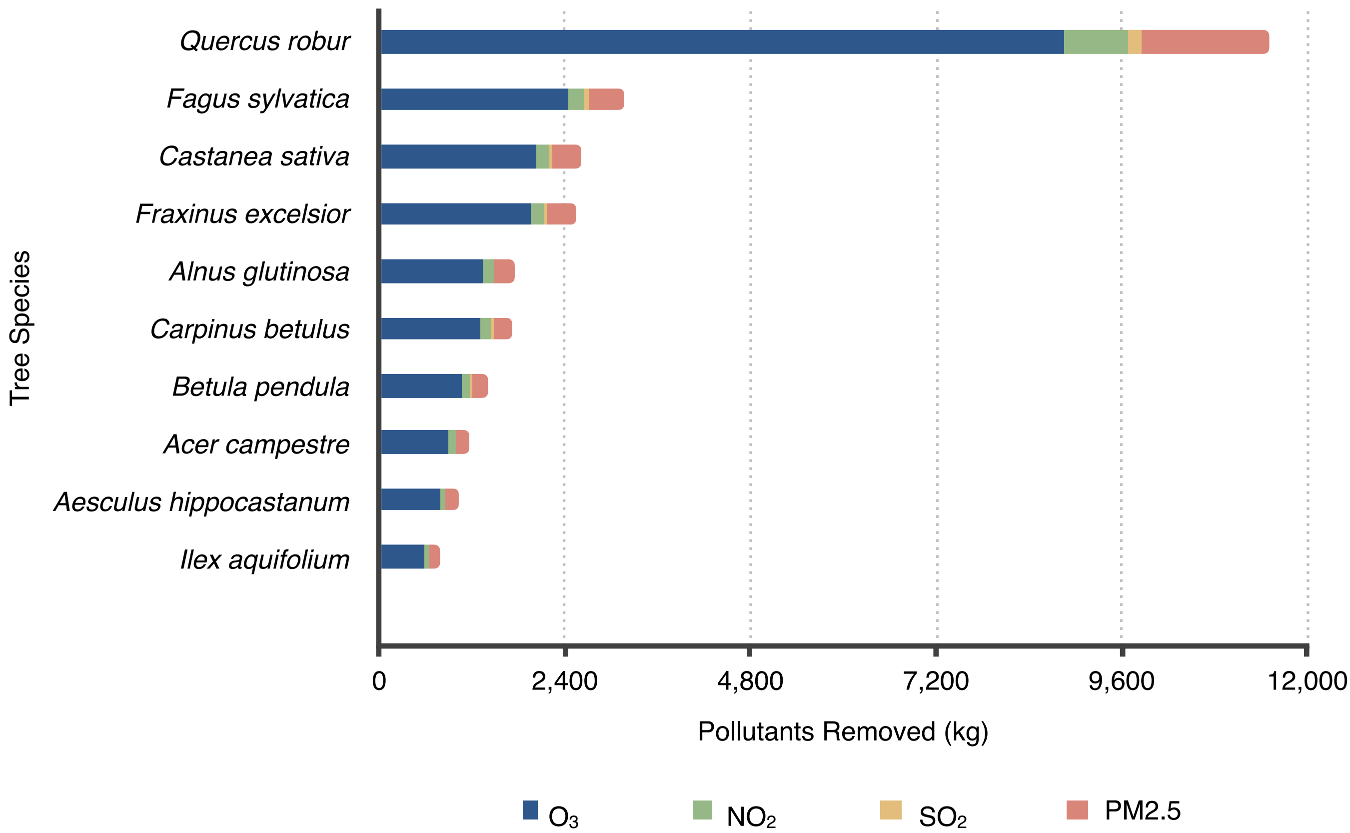

Figure 16: Pollution Removal by Tree Species

[34] Freer-Smith et al. 2005

3.2.2 Carbon Sequestration

Bexhill's trees' sequester an estimated 2,160 tonnes of carbon per year, with a value of approximately £2 million.

Table 8 (below) shows the top ten species in terms of annual carbon sequestration across Bexhill's urban forest, and the value of the benefit derived from the sequestration of this atmospheric carbon.

Species	Carbon Sequestration (tonnes/yr)	CO_2 Equivalent (tonnes/yr)	Carbon Sequestration (£/yr)
Quercus robur	643	2,360	£585,000
Fagus sylvatica	191	700	£174,000
Fraxinus excelsior	143	523	£130,000
Castanea sativa	117	430	£107,000
Aesculus hippocastanum	107	391	£97,000
Betula pendula	83	303	£75,200
Laurus nobilis	57	209	£52,000
x Cuprocyapris leylandii	57	208	£52,000
Tilia x europaea	54	198	£49,000
Prunus lusitanica	53	195	£48,300
All Other Species	**655**	**2,400**	**£595,000**
Total	**2,160**	**7,920**	**£1,960,000**

Table 8: Top Ten Carbon Sequestration by Species from across Bexhill

The trees in the 'urban' strata of Bexhill's urban forest sequester an estimated 835 tonnes of carbon annually which is 38.7% of Bexhill's urban forests total annual carbon sequestration at a value of approximately £759,000.

The trees in the 'parish' strata of Bexhill's urban forest sequester an estimated 1,060 tonnes of carbon annually which is 49.3% of Bexhill's urban forests total annual carbon sequestration at a value of approximately £967,000.

3.2.3 Carbon Storage

The main driving force behind climate change is the concentration of carbon dioxide (CO_2) in the atmosphere. Trees can help mitigate climate change by storing and sequestering atmospheric carbon as part of the carbon cycle. Since about 50% of wood by dry weight is comprised of carbon, tree stems and roots can store up to several tonnes of carbon for decades or even centuries.[35] As trees die and decompose they release the stored carbon. The carbon storage of trees and woodland is an indication of the amount of carbon that could be released if all the trees died. Maintaining a healthy tree population will ensure that more carbon is stored than released.

Overall, the trees in Bexhill's urban forest store an estimated 73,300 tonnes of carbon with a value of approximately £66.6 million. Figure 17 (below) illustrates the top ten carbon-storing tree species across Bexhill's urban forest.

The trees in the 'urban' strata of Bexhill's urban forest store an estimated 23,000 tonnes of carbon which is 31.8% of Bexhill's urban forests total carbon storage at a value of approximately £21.2 million.

The trees in the 'parish' strata of Bexhill's urban forest store an estimated 43,000 tonnes of carbon which is 58.5% of Bexhill's urban forests total carbon storage at a value of approximately £39 million.

[35] Kuhns 2008, Mcpherson 2007

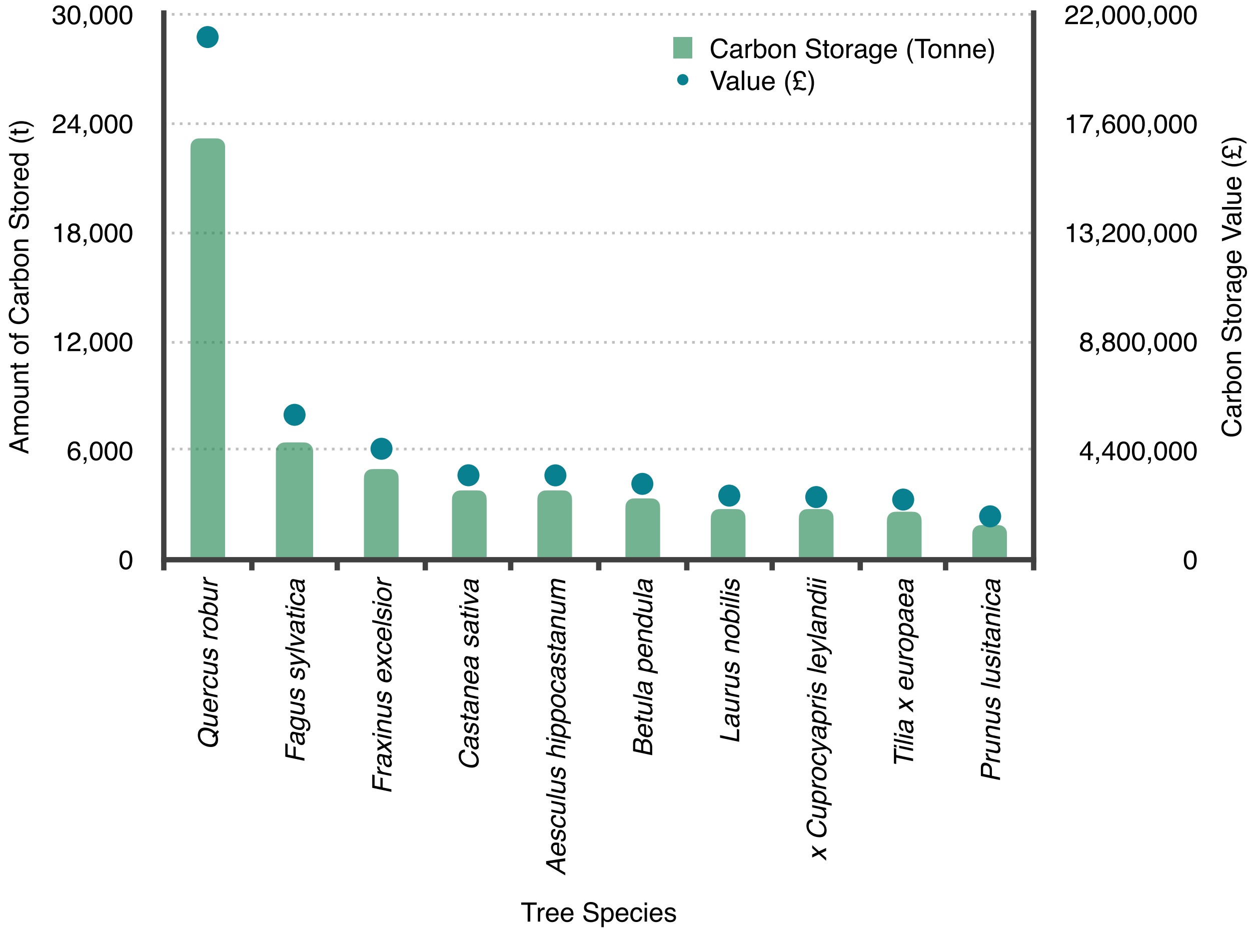

Figure 17: Carbon Storage for Top Ten Tree Species across Bexhill

Quercus robur (Oak) is the species that stores the most carbon across Bexhill, around 23,000 tonnes of carbon worth over £21 million. This is likely due to the morphology and size of trees in the population. This is followed by *Fagus sylvatica* (Beech) which stores 6,410 tonnes of carbon worth over £5.8 million.

The top ten species shown above in figure 10 species store 75.7% of the carbon within Bexhill's urban forest at a combined value of just under £50.5 million!

3.2.4 Hydrology - Avoided Surface Runoff

Surface runoff can be a cause for concern in many areas as it can contribute to flooding and is a source of pollution in streams, wetlands, waterways, lakes and oceans. During precipitation events, a proportion is intercepted by vegetation (trees and shrubs) while the remainder reaches the ground. Precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff.[36]

In urban areas, the large extent of impervious surfaces increases the amount of runoff. However, trees are very effective at reducing surface runoff.[37] Tree canopies intercept precipitation, while root systems promote infiltration and storage of water in the soil. Annual avoided surface runoff in Eco is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation.

The trees within Bexhill's urban forest reduce runoff by an estimated 84,800 m³ each year with an associated value of £152,000. This volume is equivalent to approximately 34 Olympic swimming pools of surface runoff being averted every single year.

Figure 18 (overleaf) shows the volumes and values for the ten most important species for reducing runoff across Bexhill's urban forest.

[36] Hirabayashi 2012

[37] Trees in Hard Landscapes (TDAG) 2014

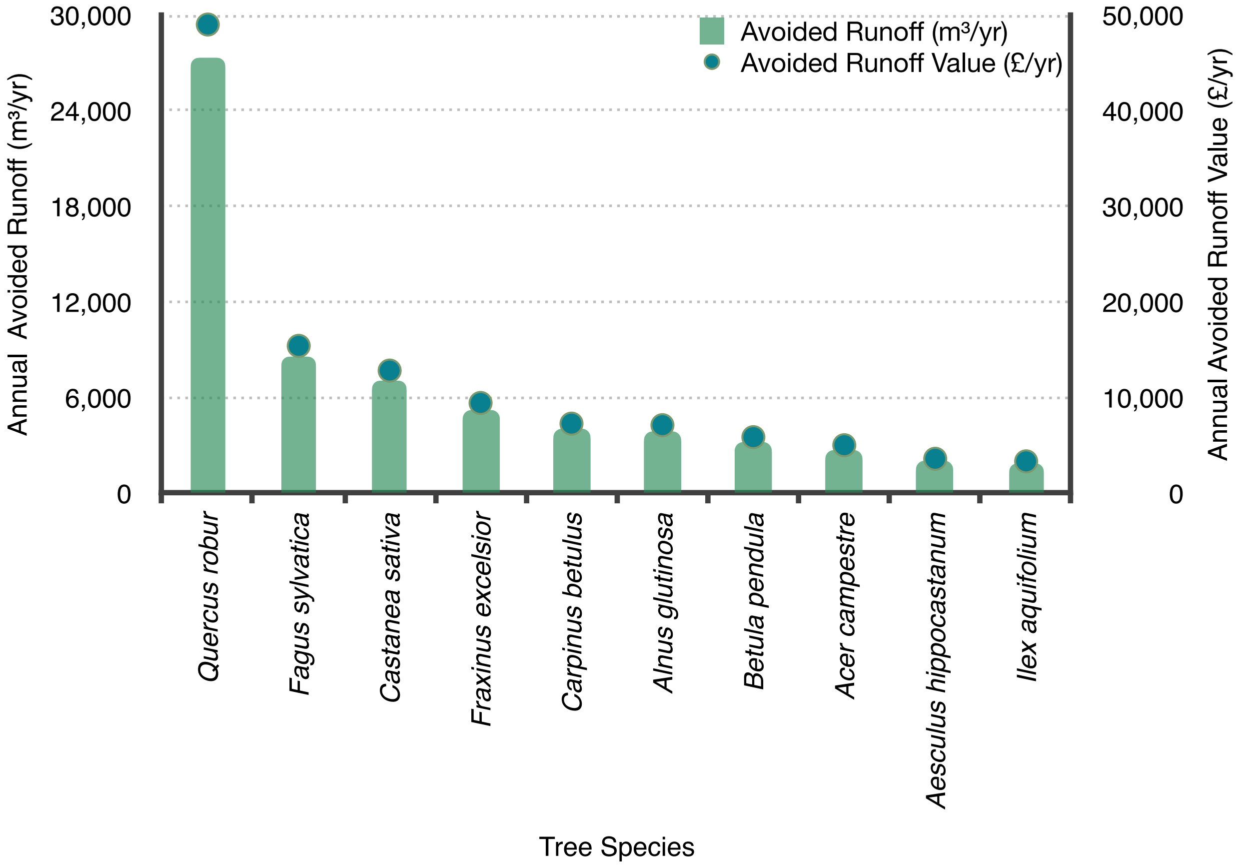

Figure 18: Annual Avoided Runoff and Associated Value by Top Ten Species

The trees in the 'urban' strata of Bexhill's urban forest reduce runoff by 19,400 m³ which is 22.9% of Bexhill's urban forests total surface runoff reduction at a value of approximately £34,900.

The trees in the 'parish' strata of Bexhill's urban forest reduce runoff by 52,000 m³ which is 61.8% of Bexhill's urban forests total surface runoff reduction at a value of approximately £94,000.

3.2.5 Additional Benefits

Trees in the urban forest have a unique role within the Town of Bexhill. They affect the immediate surroundings of the people who live and work in the area, providing benefits such as insulation, shade and clean oxygen. It is vital that these amenities are considered in planning and development to provide maximum benefits and ensure green infrastructure is incorporated where it is needed most.

Policy Context

Green infrastructure is a vital part of any townscape. It provides ecosystem services, adds amenity value to the area, and can even increase property value. As such, urban forest and green infrastructure have become key policy areas pertaining to design and development. The UN's 2030 Agenda identifies the benefits of the urban forest in SDG-8, and pushes for this to be considered in policy at a national and local level[38].

The National Planning Policy Framework (NPPF) sets out the Government's planning policies for England and provides a framework within which plans for local housing and other development can be produced. Of the 16 sections in the revised NPPF, trees are able to contribute to meeting the objectives of 11 of them. Section 12 of the NPPF "Achieving well-designed places" refers in many places to the benefit of careful consideration of the use of trees in development design. Section 14 refers to the role of planning in responding to the changing climate. Commonly referenced is trees' ability to "Conserve and enhance the natural environment" (Section 15)[39].

The UK's 25-Year Environmental Plan is based on the UN's 2030 Agenda, and has outlined six key policy areas, five of which relate to urban forest. Incorporating green infrastructure can help achieve these by connecting people with the environment to improve health and wellbeing, recovering nature and enhancing the beauty of landscapes, increasing resource efficiency, and reducing pollution and waste, and using and managing land sustainably by embedding an 'environmental net gain' principle for development, including housing and infrastructure[40].

At a local level, Bexhill has several local planning policies relating to the environment that provide guidance for developers on sustainable design and green infrastructure. These can be found and further explained in Rother District Council's Environment Strategy 2020-2030 [41] Appendix's section and include:

- Policy SRM1: Towards a low carbon future
- Policy SRM2: Water Supply and Wastewater Management
- Policy DRM1: Water Efficiency
- Policy DRM2: Renewable Energy Developments
- Policy DRM3: Energy Requirements

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38 United Nations, 2015

39 Ministry of Housing, Communities & Local Government, 2021

40 Department for Environment, Food & Rural Affairs, 2018

41 Rother District Council, 2020

The Trees & Design Action Group (TDAG) provide several guides and resources aimed at urban planners to aid the incorporation of green infrastructure within cities. The 'First Steps in Valuing Trees and Green Infrastructure' guide compiles information and guidance on the use of economic valuation approaches for trees and green infrastructure, which tool or method to choose and how to get started. It outlines four general scenarios where valuing trees and green infrastructure deliver proven results. These include: achieving greater retention of existing green assets, securing more commensurate compensation when green assets are compromised or lost, enhancing design outcomes and how those outcomes are communicated, and, enabling evidence-based management[42].

TDAG's best practice guide 'No Trees, No Future' emphasises the importance of considering trees in the early stages of design and incorporating allowances for fully mature trees from the outset. Although national and local policy tends to encourage planting trees in urban areas, the way that new development is delivered often makes it impossible to accommodate larger trees. This is a huge issue, however there are ways to overcome these challenges, for example in high density developments there may be less room for tree roots and canopies, however space can often be found along boundaries, adjacent to paths, or in areas of public open space.[43]

Whilst subsidence caused by trees is a risk perceived by many, it is actually far less common than often insinuated. One study in a London borough found that only 0.05% of its building stock was affected by tree-related insurance claims annually, and in areas where the subsoil is not shrinkable clay, the risk is minor. These types of foundation movement are likely to increase — whether or not trees are present — as the effects of climate change increase.[44] Interestingly, trees can positively affect buildings through the provision of energy saving, summertime cooling, provision of oxygen and air pollution removal.

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[42] Trees and Design Action Group, 2019

[43],[23] Trees and Design Action Group, 2010

Energy effects

Trees can provide energy saving benefits to nearby buildings through shading, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees in relation to the building. In doing so, the property typically requires less heating/cooling, and therefore uses less energy. In turn, this reduces the amount of carbon released by the traditional methods of energy production. Trees less than 3m tall or further than 18m away from buildings do not provide these benefits, and owing to the nature of the data collected it is difficult to quantify this for the whole of Bexhill.

Oxygen provision

The trees across Bexhill's provide an estimated 3,830 tonnes of oxygen each year. The average human breathes about 9.5 tonnes of air in a year, of which approximately 740.0 kg of oxygen is actually used[45]. The trees in Bexhill therefore provide breathable air to 13,300 people each year, thats 31.0% of the population of Bexhill!

UV effects

UV radiation is emitted by the sun and while beneficial to humans in small doses, can have negative health effects when people are overexposed. Trees protect people from UV rays by providing shade, blocking sunlight from directly reaching the ground. Shade provision can help keep buildings and roads cool in the summer and reduce the heat island effect associated with cities.[46]

Table 9 (below) shows the effect Bexhill's trees have on UV factors. The effects in tree shade indicates the reduction in UV for a person entirely in the shade. The UV effects

[45] https://www.theconsciouschallenge.org/ecologicalfootprintbibleoverview/oxygen-global-overview

[46] TDAG-No Trees, No Future (2010)

overall are for people in the vicinity of the tree but not always sheltered, for example walking down the street, sometimes in shade and sometimes exposed.

	Protection Factor	Reduction in UV Index	Percent reduction (%)
UV Effects in Tree Shade	1.33	0.78	24.75
UV Effects Overall	2.32	2.02	53.00

Table 9: UV Effects of Trees in Bexhill

Protection Factor is a value meant to capture the UV radiation blocking factor of trees and is comparable to the SPF factor of suncream. The UV index scale was developed by the World Health Organisation (WHO) to more easily communicate daily levels of UV radiation and alert people to when protection from overexposure is needed most.

3.2.6 Conclusions & Recommendations for Ecosystem Services

The urban forest of Bexhill removes 53.0 tonnes of pollutants, with an associated value of £1,520,000 each year. The top three species for pollution removal across Bexhill's urban forest are *Quercus robur* (Oak) with 11,500 tonnes, *Fagus sylvatica* (beech) with 3,170 tonnes and *Castanea sativ*a (Sweet chestnut) with 2,620 tonnes. These three species alone remove a total of 17,300 tonnes per year.

An estimated 2,160 tonnes of carbon is sequestered annually by the trees in Bexhill, this sequestration is valued at approximately £2 million. The top three species for carbon sequestration across Bexhill's urban forest are *Quercus robur* (Oak) with 643 tonnes at a value of £585,000, *Fagus sylvatica* (beech) with 191 tonnes at a value of £174,000 and *Castanea sativa* (Sweet chestnut) with 143 tonnes at a value of £130,000. These three species alone remove a total of 977 tonnes at a value of £889,000 per year.

The carbon storage of Bexhill's urban forest is estimated to total 73,300 tonnes, this storage is valued at approximately £66.6 million. The top three species for carbon storage include *Quercus robur* (Oak) with 23,000 tonnes at a value of £21 million, *Fagus sylvatica* (beech) with 6,410 tonnes at a value of £5.8 million and *Fraxinus excelsior* ash) with 4,904 tonnes at a value of £4.5 million. These three species alone remove a total of 101,204 tonnes at a value of £92 million per year.

The trees within Bexhill's urban forest reduce runoff by an estimated 84,800 m^3 each year with an associated value of £152,000. The top three species for carbon sequestration across Bexhill's urban forest are *Quercus robur* (Oak) with 27,300 m^3 at a value of £49,000, *Fagus sylvatica* (beech) with 8,590 m3 at a value of £15,400 and *Castanea sativa* (Sweet chestnut) with 7,150 m3 at a value of £12,800. These three species alone reduce runoff by 43,000 m3 at a value of £77,200 per year.

Therefore it is recommended that:

6. Ensure monitoring and management regimes promote the protection and enhancement of the existing, mature tree population, enabling them to thrive and perform optimal ecosystem service delivery.

7. Species are selected that are appropriate to the site to maximise tree benefit delivery and realise the full site potential. Engaging with local communities can have a large impact on the successfulness of planting initiatives, and tree wardens can be a huge asset in achieving this.

8. Prioritise planting of large-leaved long lived species over smaller, ornamental species to maximise the ecosystem services provided (where appropriate).

9. Incorporate trees and green infrastructure from the outset of urban design and planning processes. Consideration of urban forests at this stage can help to protect these valuable resources and maintain balance between green spaces and grey infrastructure.

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

4. Forecasted Ecosystem Service Provision

Forecast	0 Years	20 Years	30 Years	50 Years
Carbon Storage				
(Tonnes)	73,300	129,000	165,000	247,000
(£)	£18,200,000	£32,000,000	£40,900,000	£61,300,000
Carbon Sequestration				
(Tonnes)	2,160	3,360	3,790	4,350
(£)	£535,000	£833,000	£941,000	£1,080,000
Pollution Removal by trees.				
(Tonnes)	34	47	54	67
(£)	£895,000	£1,670,000	£1,910,000	£2,370,000
Total Annual Benefits	**£1,430,000**	**£2,500,000**	**£2,850,000**	**£3,450,000**

Table 10: Forecasted Ecosystem Service Provision with no mortality at 0, 20, 30 and 50 years

Table 10 (above) shows the forecasted ecosystem service provision with no mortality. Year 0 shows the current benefits that have been highlighted through this report. Looking ahead the i-Tree Eco forecast tool was run so as to give an idea of what the current urban forest of Bexhill will deliver in terms of ecosystem service provision and benefits in the future. The increase in total annual benefits over time can be seen as can the cumulative benefits of carbon storage over time.

Forecast uses structural estimates, environmental and location variables, species characteristics along with growth and mortality rates to forecast future tree DBH and crown size. Forecasted benefits are then estimated based on the projected tree growth and leaf area.

Table 10 shows forecasted ecosystem service provision with no mortality which is an idealised situation.

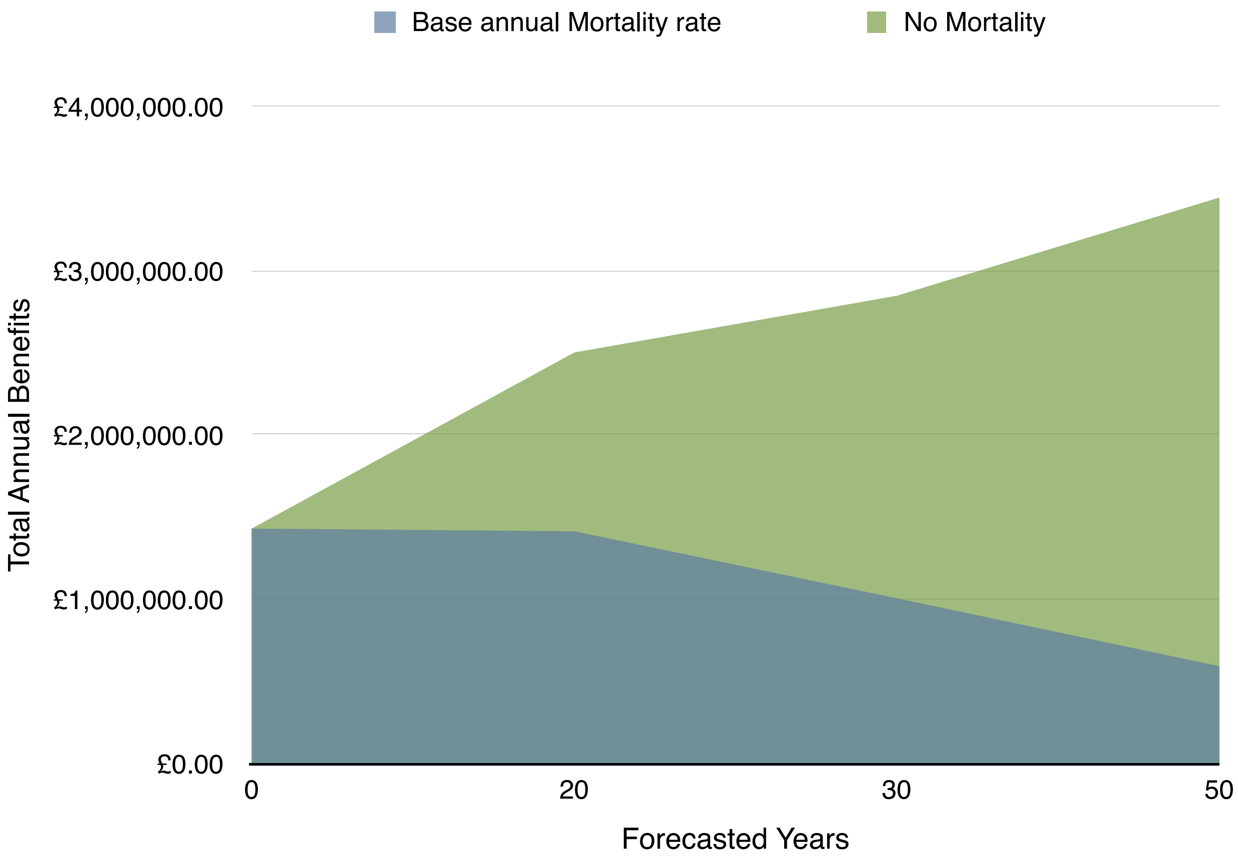

Figure 19: Standard mortality against no mortality total annual benefits

Figure 19 (above) shows the projected difference in total annual benefits of Bexhill's Urban Forest in two differing forecast scenarios. The “base annual mortality" trend line can be scene as a ‘do nothing’ scenario. This trend line shows how the current value of Bexhill’s Urban Forest will depreciate over time if not maintained and bolstered by future planting and management due to a base annual mortality rate of trees over time.

Comparatively the trend line showing “no mortality” can be used as an approximate model of Bexhill's future Urban Forest’s total annual benefits if well managed and added to strategically going forward. This scenario would offset the natural mortality of trees over time allowing access to the appreciating trend in the value of Bexhill’s Urban Forest.

5. CAVAT - The amenity value of trees

Capital Asset Valuation of Amenity Trees (CAVAT) provides a means of managing trees as public assets, rather than as liabilities by placing a value on the amenity benefits trees provide. The values derived from using the tool can be used not only in decision-making and strategic thinking, but also can be applied to individual cases where the value of a single tree needs to be expressed in monetary terms.

Bexhill's urban forest has an estimated public amenity asset value of **£3.28m** determined using an amended version of the CAVAT Quick Method valuation tool.[47]

This method is a reduced version of the full CAVAT method and takes into account the size and health of trees as well as their public accessibility.

Quercus robur (Oak) had the highest overall value, representing 70% of the total public amenity value of all the trees in Bexhill's urban forest. Large, healthy and long-lived trees in more prominent locations generally provide greatest amenity value.

The single most valuable tree was a *Quercus robur* (Oak), with an estimated CAVAT asset value of £1,660,000. This was a large, mature Oak tree in a private garden with a healthy crown and a DBH of 3.6 metres (Figure 20).

The top 10 individual trees for amenity value can be found in Table 21 (below_.

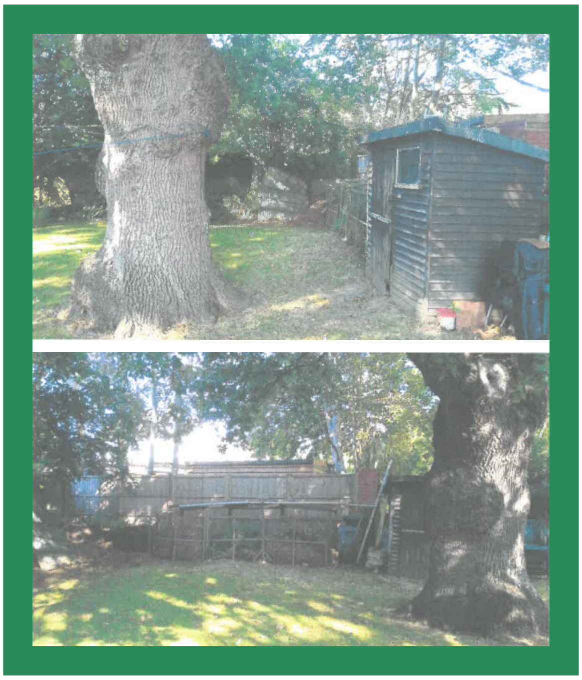

Figure 20: *Quercus robur* (Oak) with the highest estimate CAVAT value in Bexhill

[47] Doick, K.J., Neilan, C., Jones, G., Allison, A., McDermott, I., Tipping, A., Haw, R., 2018. CAVAT (Capital Asset Value for Amenity Trees): valuing amenity trees as public assets. *Arboricultural Journal* 1–25.

Residential land contained the highest CAVAT values of trees, with 82.0% of the total value of trees and an estimated value of approximately £2.69 million. Unusually, trees in parks contributed less to the overall amenity value than trees in most other land uses (Figure 18).

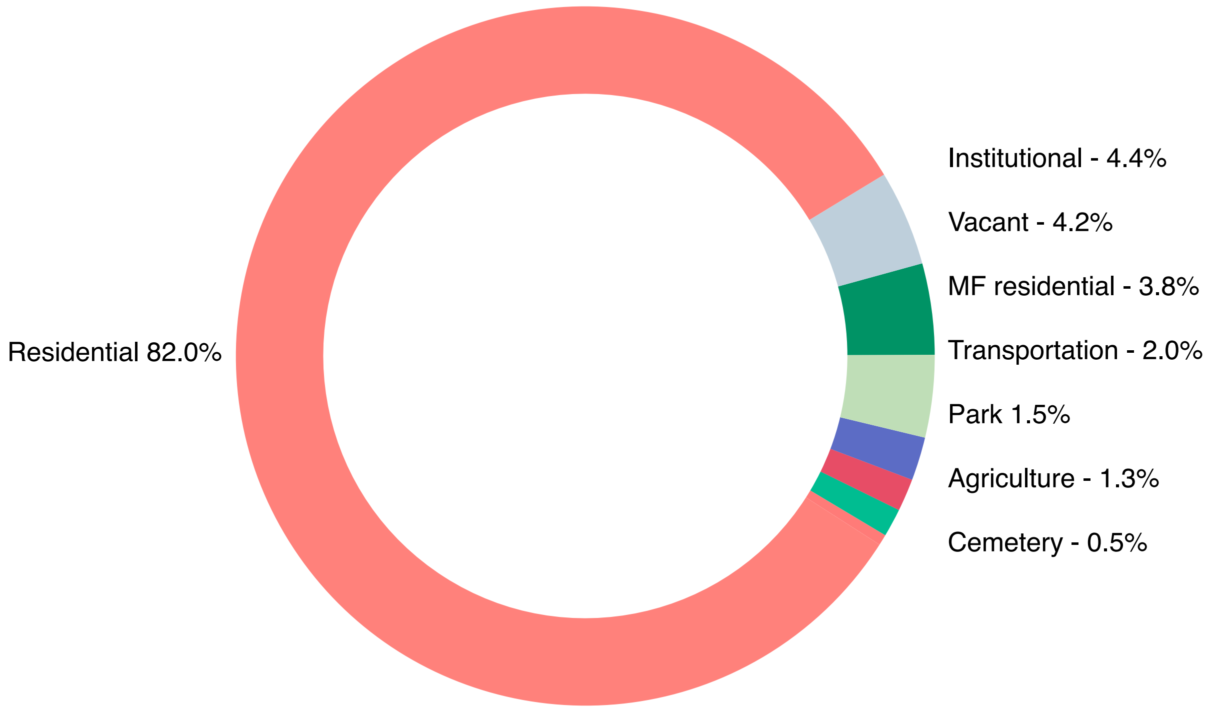

Figure 21: Percentage of the public amenity value held by urban trees in Bexhill according to land use.

Species	DBH	Land use	CAVAT Value
Quercus robur (Oak)	3.6 metres	Residential	£1.65 million
Tilia x europaea (lime)	1.1 metres	Multi-family residential	£119,000
Quercus robur (Oak)	98.0 cm	Residential	£62,300
Quercus robur (Oak)	72.0 cm	Residential	£53,000
Aesculus hippocastanum (Horse chestnut)	65.0 cm	Residential	£51,300
Quercus spp. (Oak spp.)	60.0 cm	Residential	£46,000
Cupressus spp. (Cypress spp.)	58.0 cm	Residential	£32,700
Quercus ilex (Holm oak)	72.0 cm	Institutional	£31,800
Quercus robur (Oak)	50.0 cm	Residential	£25,500
Quercus robur (Oak)	50.0 cm	Residential	£25,500

Table 11: The top 10 recorded urban trees in Bexhill for their amenity value

6. Combe Valley Countryside Park

Structure and Composition Combe Valley Countryside Park	
Number of Trees (estimate)	**35,650**
Average Tree Density (estimate of trees per hectare)	**60**
Tree Cover	**15.5%**
Shrub Cover	**2.7%**
Total Canopy Cover (Tree + Shrub Cover)	**18.2%**
Number of Species Surveyed	**18**
Shannon Weiner Index	**2.6**
Most Common Tree Species	***Quercus robur, Fraxinus excelsior, Crataegus monogyna***
Replacement Cost	**£13,800,000**

Table 12: Combe Valley Countryside Park Structure and Composition Headline Figures

Species and Diversity

The Countryside Park is host to 18 species. The three most common species are *x Quercus robur* (Oak) 17.7%, *Fraxinus excelsior* (Ash) 13.7% and *Crateagus monogyna* (Hawthorn) 12.1%. They collectively make up 43.5% of the parks 35,650 trees. The Countryside park's Shannon Weiner index is 2.6.

Leaf area

In the Combe Valley Countryside Park the three most dominant tree species in terms of leaf area are *Quercus robur* (Oak) 24.7%, *Salix fragilis* (Crack willow) 13.1% and *Castanea sativa* (Sweet chestnut) 11.9%. Collectively they make up 49.7% of the parks total leaf area.

Replacement Cost

There are an estimated 35,650 trees in the Combe Valley Countryside Park. Making up 15.6% of Bexhill's urban forests tree total. The total replacement cost for these trees according to Eco is over £13.5 million accounting for 9.7% of the total urban forest's replacement cost.

Ecosystem Services Headline Figures		
Carbon Storage (whole value)	26,000 Tonnes	£23,6,000
Carbon Sequestration (annual)	955 Tonnes	£869,000
Pollution Removal (annual)	8.4 Tonnes	£242,000
Avoided Runoff (annual)	12,900 m³	£23,200
Total Annual Benefits	£1,130,000	

Table 13: Combe Valley Countryside Park Ecosystem Service Headline Figures

Carbon Sequestration

The trees in the Combe Valley Countryside Park sequester an estimated 955.7 tonnes of carbon annually, that's 12.1% of Bexhill's urban forests total annual carbon sequestration at a value of approximately £237,000.

Carbon Storage

The trees in Combe Valley Countryside Park store 7,080 tonnes of carbon, thats 9.7% of Bexhill's urban forests total carbon storage at a value of £6.4 million.

Pollution Removal

Given the percentage of trees in the Combe Valley Countryside Park relative to Bexhill's total urban forest population, the estimated pollution removal by the trees in the Combe Valley Countryside Park of Bexhill's urban forest is 5.9 tonnes of pollutants. The Combe Valley Countryside Park therefore makes up 15.3% of Bexhill's urban forests total pollutant removal. However this is not representative of the species breakdown within the 'Countryside Park' strata due to i-Tree limitations.

Hydrology Effects

The trees in Combe Valley Countryside Park reduce runoff by 12,940 m^3, that's 15.3% of Bexhill's urban forests total surface runoff reduction at a value of approximately £23,200.

7. Conclusions

The tree population within Bexhill's urban forest has a good species diversity, with 81 species identified. It is acknowledged that there are a number of constraints on urban and highway planting that can hinder planting of larger-growing species. The role of Bexhill’s trees in complementing people's health is clear, through air pollution removal especially.

Bexhill's urban forest’s trees provide a valuable benefit of over £3,630,000 in ecosystem services each year and store 73,200 tonnes of carbon at a value of over £66 million.

The most common species is *Quercus robur* (Oak) accounting for 18.7% of the total population, which is significantly more than any other species, and indicates a reliance on this species which may reduce the resilience of Bexhill’s urban forest especially when considering Ash Dieback. The top 10 most common species account for 67.3% of all trees, store more than half of the total amount of carbon, sequester 5,280 tonnes of carbon each year and reduce the town’s surface runoff by 58,000m^3 each year worth £104,000 in avoided sewerage charges.

Like many urban areas, Bexhill’s urban forest would benefit from having a greater proportion of larger trees, and improved species diversity and balance in order to continue deliver greater benefit and promote structural diversity in its tree population. Larger-growing trees are important because they can provide greater canopy cover and therefore ecosystem service provision. They also tend to have higher amenity value than their smaller counterparts.

The values presented in this study should be seen as conservative estimates, only a proportion of the total potential benefits have been evaluated. Trees confer many benefits which have not been valued as part of this report, such as contributions to our health and well-being, reducing urban temperatures, providing amenity value and habitats for wildlife.[48]

The extent of these benefits needs to be recognised. Strategies and policies that will conserve this important resource (through education for example) would be one way to address this. Targets to increase canopy cover including planting larger trees, protecting large and veteran trees and, where possible, continue to diversify the urban forest through planting climate adaptable species should also be investigated through the production of an 'Urban Forest Masterplan'. Introducing and enforcing policies regarding the incorporation of green infrastructure in planning and design would go a long way to helping ensure trees reach their full potential in the urban environment. As the amount of healthy leaf area equates directly to the provision of benefits, consistent and considered management of the tree stock is important to ensure canopy cover levels continue to be maintained or increased. New tree planting can contribute to the growth of canopy cover. However, the most effective strategy for increasing average tree size and the extent of tree canopy is to adopt a management approach that enables a sustainable, healthy, age and species diverse tree population. This means that protecting existing tree stock is vital, and planning for tree growth must be taken into account before planting, to ensure the trees can remain a long-term, nature based solution to the challenges ahead.

Climate change could affect the tree stock in Bexhill's urban forest in a variety of ways and there are great uncertainties about how this may manifest. Some species may be less able to survive under new climatic conditions. New climatic conditions may also allow new and present pests and diseases to become prevalent or to change their

[48] Davies *et al*, 2017

behaviours. Further studies into this area would be useful in informing any long-term tree strategies or urban forest masterplans, that carefully consider species selection.

The challenge now is to ensure that policy makers and practitioners take full account of Bexhill's trees in decision making. Not only are trees a valuable functional component of our landscape, they also make a significant contribution to people's quality of life. Incorporating the urban forest and green infrastructure into planning and design from the outset is vital to ensuring that Bexhill can make the most of its space and maximise the benefits of trees for generations to come.

8. Appendices

Appendix I. Relative Tree Effects

The urban forest of Bexhill provides benefits that include carbon storage and sequestration, air pollutant removal and reducing surface runoff. To estimate the relative value of these benefits, tree benefits were compared to estimates of average carbon emissions and average family car emissions. These figures should be treated as a guideline only as they are largely based on US values (see footnotes).

Carbon storage is equivalent to:

- Amount of carbon emitted in Bexhill in 61 days
- Annual carbon (C) emissions from 57,000 automobiles
- Annual C emissions from 23,400 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 12 automobiles
- Annual carbon monoxide emissions from 33 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 572 automobiles
- Annual nitrogen dioxide emissions from 33 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 9,940 automobiles
- Annual sulfur dioxide emissions from 26 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Bexhill in 1.8 days
- Annual C emissions from 1,700 automobiles
- Annual C emissions from 700 single-family houses

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

Light duty vehicle emission rates (g/mi) for CO, NO_x, VOCs, PM, SO_2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5for 2011-2015 (California Air Resources Board 2013), and CO_2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

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

- CO_2, SO_2, and NO_x power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM emission per kWh from Layton 2004.
- CO_2, NO_x, SO_2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO_2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NO_x and SO_2 emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

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

Appendix II. Species Dominance Ranking List

Species	Percent Population	Percent Leaf Area	Dominance Value
Oak	18.7	32.2	50.9
Ash	8.7	6.2	14.9
Beech	4.1	10.1	14.2
Sweet chestnut	3.0	8.4	11.4
Silver birch	7.3	3.9	11.1
Holly	7.8	2.2	10.0
Oneseed hawthorn	7.0	1.8	8.8
European hornbeam	2.0	4.8	6.8
European alder	1.9	4.7	6.6
Leyland cypress	4.9	0.7	5.6
Hedge maple	2.2	3.3	5.5
European filbert	3.0	1.9	4.9
Horse chestnut	1.9	2.4	4.3
Goat willow	2.6	1.7	4.2
Sycamore maple	2.9	1.0	3.9
Crack willow	1.6	2.0	3.6
Lime	0.6	1.9	2.5
Blackthorn	2.0	0.3	2.3
Portugal laurel	1.2	0.9	2.1
White poplar	0.8	1.1	1.9
Bay laurel	1.3	0.5	1.8
cypress spp	0.6	1.0	1.6
willow spp	0.8	0.8	1.5
White willow	0.8	0.6	1.5
European black elderberry	1.1	0.2	1.3
Holly Oak	0.1	1.1	1.2
Paradise apple	1.1	0.1	1.2
Scots pine	0.6	0.6	1.2
Western redcedar	0.7	0.2	0.8
Northern red Oak	0.2	0.6	0.8
Large gray willow	0.5	0.3	0.8

Species	Percent Population	Percent Leaf Area	Dominance Value
plum spp	0.4	0.3	0.7
Common plum	0.5	0.0	0.6
Sweet cherry	0.5	0.1	0.6
Oak spp	0.1	0.5	0.5
Laurel willow	0.4	0.1	0.5
Austrian pine	0.4	0.1	0.5
pine spp	0.2	0.3	0.5
European mountain ash	0.4	0.0	0.4
English yew	0.4	0.0	0.4
Bigleaf linden	0.1	0.3	0.3
Indian paper birch	0.3	0.1	0.3
elm spp	0.3	0.0	0.3
magnolia spp	0.2	0.1	0.3
Cherry plum	0.2	0.0	0.2
European aspen	0.2	0.0	0.2
Honeylocust	0.2	0.0	0.2
Whitebeam	0.2	0.0	0.2
Olive	0.2	0.0	0.2
Babylon weeping willow	0.1	0.1	0.2
White mulberry	0.1	0.1	0.2
rhododendron spp	0.2	0.0	0.2
Downy birch	0.2	0.0	0.2
maple spp	0.1	0.0	0.1
Sweetgum	0.1	0.00	0.1
gum spp	0.1	0.0	0.1
broom spp	0.1	0.0	0.1
River birch	0.1	0.0	0.1
Common ash	0.1	0.0	0.1
smoketree spp	0.1	0.0	0.1
Southern catalpa	0.1	0.00	0.1
juniper spp	0.1	0.0	0.1
spruce spp	0.1	0.0	0.1
Monterey cypress	0.1	0.0	0.1
Smoke tree	0.1	0.0	0.1

Species	Percent Population	Percent Leaf Area	Dominance Value
Juneberry	0.1	0.0	0.1
European larch	0.1	0.0	0.1
cedar spp	0.1	0.0	0.1
Smooth hawthorn	0.1	0.0	0.1
windmill palm spp	0.1	0.0	0.1
Japanese red cedar	0.1	0.00	0.1
Golden weeping Willow	0.1	0.00	0.1
Staghorn sumac	0.1	0.00	0.1
fig spp	0.1	0.00	0.1
Golden-chain tree	0.1	0.00	0.1
Common pear	0.1	0.00	0.1
yucca spp	0.1	0.00	0.1
Windmill palm	0.1	0.00	0.1
Atlas cedar	0.1	0.00	0.1
Fraser photinia	0.1	0.00	0.1
Common fig	0.1	0.00	0.1

Appendix III. Replacement Cost by Species

Species	Trees	Carbon Storage (tonnes)	Gross Carbon Seq (tonnes/ Yr)	Avoided Runoff (m³/Yr)	Pollution Removal (tonnes/ Yr)	Replacement Cost (£)
Oak	42629	23178	643	27292	12.4	£53,119,185
Ash	19775	4904	117	5259	2.4	£4,917,903
Holly	17741	915	41	1860	0.9	£2,364,730
Silver birch	16592	3346	143	3268	1.5	£5,342,274
Oneseed hawthorn	15862	1852	54	1545	0.7	£3,111,565
Leyland cypress	11233	2760	191	573	0.3	£2,235,804
Beech	9292	6411	83	8585	3.9	£15,230,602
European filbert	6862	985	27	1610	0.7	£2,620,313
Sweet chestnut	6744	3727	107	7146	3.3	£8,279,487
Sycamore maple	6626	855	33	863	0.4	£1,479,797
Goat willow	5881	1352	25	1403	0.6	£4,488,784
Hedge maple	5063	1596	16	2799	1.3	£3,414,272
European hornbeam	4611	820	26	4057	1.9	£1,196,203
Blackthorn	4531	194	31	261	0.1	£432,935
Horse chestnut	4442	3724	57	2011	0.9	£3,099,779
European alder	4417	294	14	3967	1.8	£2,535,076
Crack willow	3737	587	26	1695	0.8	£1,877,764
Bay laurel	3024	2824	57	397	0.2	£3,808,107
Portugal laurel	2690	1905	53	798	0.4	£3,168,846
Paradise apple	2592	445	29	74	0.0	£1,019,305
European black elderberry	2470	170	10	174	0.1	£262,528
White willow	1921	467	25	550	0.3	£1,212,256
White poplar	1798	704	24	933	0.4	£1,791,340
willow spp	1728	1118	24	636	0.3	£841,092
Western redcedar	1512	63	1	135	0.1	£1,211,035
Scots pine	1343	276	12	491	0.2	£793,791
Lime	1296	2649	48	1630	0.7	£3,515,703
cypress spp	1296	1568	37	858	0.4	£1,174,321
Common plum	1248	65	11	27	0.0	£80,941

Species	Trees	Carbon Storage (tonnes)	Gross Carbon Seq (tonnes/ Yr)	Avoided Runoff (m^3/Yr)	Pollution Removal (tonnes/ Yr)	Replacement Cost (£)
Large gray willow	1150	74	16	229	0.1	£94,448
Sweet cherry	1080	100	8	80	0.0	£182,004
Austrian pine	864	141	4	98	0.0	£591,722
plum spp	864	211	11	296	0.1	£310,398
European mountain ash	864	31	3	37	0.0	£52,266
Laurel willow	862	147	13	109	0.1	£163,502
English yew	816	19	1	16	0.0	£26,896
elm spp	648	115	4	35	0.0	£66,081
Indian paper birch	648	24	3	46	0.0	£50,599
magnolia spp	432	37	5	54	0.0	£84,486
Honeylocust	432	17	3	19	0.0	£48,128
Whitebeam	432	4	1	12	0.0	£37,262
Olive	432	14	2	11	0.0	£33,282
Cherry plum	432	28	4	35	0.0	£33,094
Northern red Oak	384	370	18	526	0.2	£1,313,191
pine spp	384	515	14	271	0.1	£909,636
European aspen	384	103	6	41	0.0	£242,336
rhododendron spp	384	179	5	16	0.0	£136,588
Downy birch	384	4	0	4	0.0	£19,979
Holly Oak	216	436	14	973	0.4	£1,473,782
Oak spp	216	238	9	386	0.2	£824,858
Bigleaf linden	216	53	4	216	0.1	£196,776
White mulberry	216	28	2	82	0.0	£141,436
River birch	216	70	3	15	0.0	£130,387
windmill palm spp	216	8	1	4	0.0	£79,610
Golden weeping Willow	216	206	2	3	0.0	£79,154
maple spp	216	61	4	31	0.0	£78,795
Monterey cypress	216	29	2	8	0.0	£50,380
gum spp	216	6	1	18	0.0	£37,235
yucca spp	216	3	1	1	0.0	£35,642
Babylon weeping willow	216	30	4	87	0.04	£27,876

Species	Trees	Carbon Storage (tonnes)	Gross Carbon Seq (tonnes/ Yr)	Avoided Runoff (m^3/Yr)	Pollution Removal (tonnes/ Yr)	Replacement Cost (£)
Fraser photinia	216	29	3	1	0.00	£25,818
broom spp	216	21	2	18	0.0	£24,745
Common pear	216	9	2	2	0.0	£19,493
Juneberry	216	21	2	6	0.0	£19,227
Windmill palm	216	15	0	1	0.0	£19,028
Golden-chain tree	216	15	3	2	0.00	£19,018
Common ash	216	11	2	12	0.01	£16,980
Atlas cedar	216	2	1	1	0.0	£16,201
juniper spp	216	20	3	9	0.0	£15,227
Southern catalpa	216	1	0	9	0.00	£14,421
Staghorn sumac	216	2	0	3	0.0	£14,421
Common fig	216	3	1	0	0.0	£14,421
Smooth hawthorn	216	2	0	4	0.00	£13,268
fig spp	216	7	1	3	0.00	£13,268
Japanese red cedar	216	2	1	4	0.00	£12,646
spruce spp	216	13	3	9	0.00	£12,529
cedar spp	216	10	2	4	0.00	£12,475
smoketree spp	216	7	1	11	0.0	£11,207
Sweetgum	216	3	0	20	0.01	£9,837
Smoke tree	216	6	1	7	0.00	£9,837
European larch	216	3	0	6	0.00	£4,384
Total	**227,960**	**73,252**	**2,159**	**84,788**	**38.6**	**£142,496,021**

Appendix IV. Pests and Disease

Acute Oak Decline

Acute Oak decline (AOD) mainly affects mature trees (>50 years) of both native Oak species (*Quercus robur* and *Q. petraea*) and a variety of other Oak species including:

- *Q. fabri*
- *Q. ilex*
- *Q. aliena var. accuserrata*
- *Q. palustris*
- *Q. pyrenaica*
- *Q. rubra*
- *Q. coccinea*
- *Q. cerris*
- *Q. nigra*

Of the species affected by Acute oak decline (listed above), *Quercus ilex, Quercus robur and Quercus rubra* were all identified as part of the i-Tree Eco field surveys. Some affected trees can die in as little as 4-6 years after symptoms have developed. Over the past few years, the reported incidents of stem bleeding and exit holes of the associated beetle *Agrilus bigatatus*, indicating potential AOD infection, have been increasing. The latest distribution map (Figure 19) shows a spread in cases westward and to the midlands. Figure 20 shows that it is highly probable that Bexhill's Oak trees would be affected by AOD (based on modelling of predisposition factors including temperature, rainfall, and levels of atmospheric nitrogen pollution).

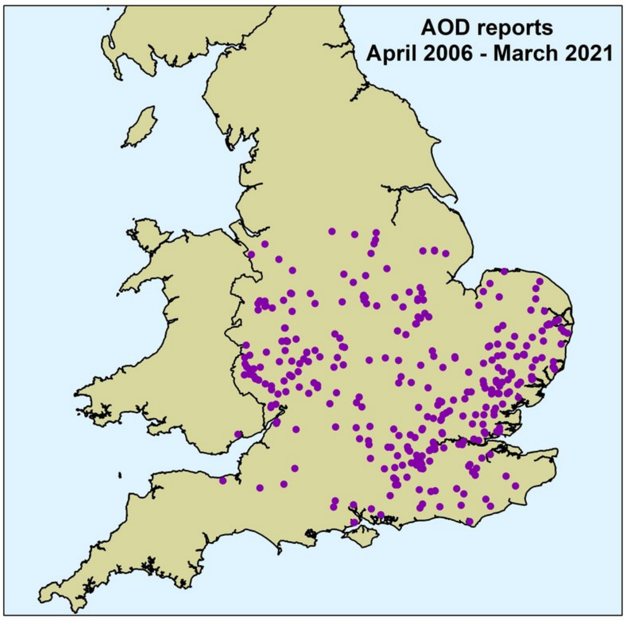

Figure 19: Locations where AOD has occurred between 2006-March 2021

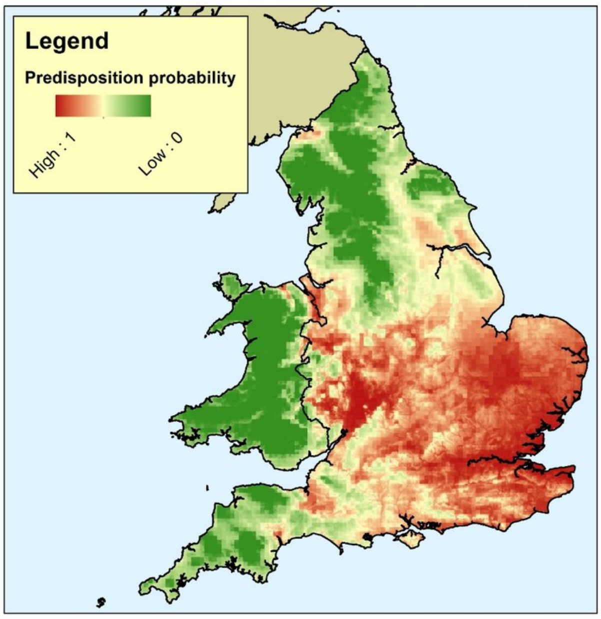

Figure 20: Probability of where AOD might occur based on modelling of predisposition factors

Asian Longhorn Beetle

The Asian longhorn beetle (*Anoplophlora glabripennis*) is a major pest in China, Japan and Korea, where it kills many broadleaved species. There are established populations of Asian longhorn beetle (ALB) in parts of North America and have been outbreaks in Europe too. Where the damage to street trees is high, felling, sanitation and quarantine are the only viable management options. 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. The known host tree and shrub species include:

- Alder (*Alnus* species)
- American pin Oak (*Quercus palustris*)
- Apple (*Malus spp.*)
- Ash (*Fraxinus spp.*)
- Beech (*Fagus spp.*)
- Birch (*Betula spp.*)
- Cherry and plum (*Prunus spp.*)
- Elm (*Ulmus spp.*)
- False acacia/black locust (*Robinia pseudoacacia*)
- Goldenrain tree (*Koelreuteria paniculata*)
- Hazel (*Corylus spp.*)
- Hornbeam (*Carpinus spp.*)
- Horse chestnut (*Aesculus spp.*)
- Japanese pagoda tree (*Styphnolobium japonicum Schott*)
- Katsura tree (*Cercidiphyllum japonicum*)
- Maples and sycamores (*Acer species*)
- Mimosa silk tree (*Albizia julibrissin*)
- North American red Oak (*Quercus rubra*)
- Pear (*Pyrus spp.*)
- Plane (*Platanus spp.*)
- Poplar (*Populus spp.*)
- Rowan/mountain ash, whitebeam (*Sorbus spp.*)
- Willow and sallow (*Salix spp.*)

Bronze Birch Borer

The Bronze birch borer (*Agrilus anxius*) is a wood-boring beetle that feeds on the inner bark and cambium of birch trees. The disruption to water and nutrient flow that occurs as a result means that trees can die within a few years after symptoms appear. At current, the Bronze birch borer is present across North America, including the United States, where it is native, and Canada. Here, the borer has caused extensive mortality of *Betula spp.* planted as street and ornamental trees in towns and cities, due to its ability to colonise most birch species and cultivars.

Chalara Dieback of Ash

Ash Dieback, caused by the fungus *Hymenoscyphus fraxineus*, is a highly destructive disease of ash trees, including *Fraxinus excelsior*, *F. excelsior 'Pendula'* and *F. angustifolia*. Young trees are particularly susceptible and can be killed within one growing season of symptoms becoming visible. Older trees can take longer to succumb, but can die from the infection or secondary pathogens (e.g. *Armillaria*) after several seasons. *H. fraxineus* was first recorded in the UK in 2012 in Buckinghamshire and is now widespread across the UK, including in urban areas. It is in these urban areas, along transport routes and rights of way/footpaths, that the dieback of the tree's woody components as a result of infection presents a significant health and safety risk.

Emerald Ash Borer

Emerald ash borer (EAB) is likely to have a major impact on our already vulnerable ash population in the UK if established. There is no evidence to date that EAB is present in the UK, but the increase in global movement of imported wood and wood packaging heightens the risk of its accidental introduction. EAB is present in Russia and Ukraine and is moving West and South at a rate of 30-40 km per year, perhaps aided by vehicles.[49] EAB has had a devastating effect in the USA due to its accidental

[49] Straw et al., 2013

introduction and could add to pressures already imposed on ash trees from diseases such as Chalara dieback of ash.

Larger eight-toothed spruce bark beetle

The larger eight-toothed spruce bark beetle (*Ips typographus*) is a pest of conifers, including those of the spruce genus (*Picea spp.*), fir trees (*Abies spp.*), pines (*Pinus spp.*) and larch trees (*Larix spp.*). The beetles tend to favour stressed trees, such as those that have been windblown or recently felled. However, they can also move to nearby live trees and cause significant damage by carving out galleries so that they can lay their eggs. *Ips typographus* can also spread pathogenic fungi between trees, such as the blue-stain fungus (*Endoconidiophora polonica*), which can weaken trees further.

Oak Processionary Moth

Oak processionary moth (OPM) was first accidentally introduced to Britain in 2005 and now there are established OPM populations in most of Greater London and in some surrounding counties. It is thought that OPM has been spread through imported nursery trees and it has been estimated that OPM could survive and breed in much of England and Wales. The caterpillars cause serious defoliation of Oak trees, their principal host, which can leave them more vulnerable to other stresses. The caterpillars have urticating (irritating) hairs that can 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 in recent years. Whilst the outbreak in London is beyond eradicating, the rest of the UK maintains its European Union Protected Zone status (PZ) and restrictions on moving Oak trees are in place to minimise the risk of further spread.

Xylella fastidiosa

*Xylella fastidios*a is a bacterium that has the potential to cause significant damage to a range of broadleaf trees and commercially grown plants. The bacterium has been found in Italy, France, Spain, the Americas and Taiwan, and can be spread through the movement of infected plant material and through insects from the *Cicadellidae* and *Ceropidae* families. There are four known sub-species: *Xylella fastidiosa subsp. multiplex, Xylella fastidiosa subsp. fastidiosa, Xylella fastidiosa subsp. pauca and Xylella fastidiosa subsp. Sandyi*. The subspecies multiplex is thought to be able to infect the widest variety of trees and plants, including *Quercus robur* and *Platanus occidentalis*.

For further information on the pests and diseases listed above, as well as other pathogens that pose a threat to the UK's trees, please visit https://www.forestresearch.gov.uk/tools-and-resources/pest-and-disease-resources

Appendix V. Notes on Methodology

Data Formatting

Life Expectancy (years)	Condition Rating	i-Tree Equivalent
80 +	Good Condition	87%
40 - 80	Good Condition	87%
10 - 20	Fair Condition	82%
20 - 40	Fair Condition	82%
< 5	Poor Condition	62%
05 - 10	Poor Condition	62%
None	Fair	82%

Table 14: Condition Ratings for use in Eco

Crown Condtion	LE Value	LE Percentage
87%	40 - 80	95%
82%	20 - 40	80%
62%	10 - 20	55%
0	0	0%

Table 15: CAVAT Assumptions

i-Tree Methodology

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

- Forest structure (e.g., species composition, tree health, leaf area, etc.)
- Amount of pollution removed hourly by trees, and its associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulphur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<2.5 microns).
- Total carbon stored and net carbon annually sequestered by trees
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease

To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations.[50] To adjust for this difference, biomass results for open-grown urban trees were multiplied

[50] Nowak 1994

by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.
To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O_2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of trees account for decomposition.[51]

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

Air pollution removal estimates are derived from calculated hourly tree canopy resistances for ozone, sulphur dioxide and nitrogen dioxide based on a hybrid of big-leaf and multi-layer canopy deposition models.[52] 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[53,54] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere.[55]

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[51] Nowak, David J., Hoehn, R., and Crane, D. 2007.

[52] Baldocchi 1987, 1988

[53] Bidwell and Fraser 1972

[54] Lovett 1994

[55] Zinke 1967

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis. The value of avoided runoff is based on estimated or user-defined local values.

Replacement Costs were based on the valuation procedures of the Council of Tree and Landscape Appraisers, which use tree species, diameter, condition and location information.[56]

[56] Hollis, 2007

Appendix VI. CAVAT

An amended version of the CAVAT "quick" method was chosen to assess the trees in Bexhill (urban area only). To reach a CAVAT valuation the following information was obtained:

- the current unit value factor rating (£16.26 for 2021/22)
- DBH of each tree measured in the survey
- the Community Tree Index rating (CTI), reflecting local population density
- an assessment of accessibility
- an assessment of overall functionality, (the health and completeness of the crown of each tree measured)
- an assessment of life expectancy for each tree measured

The unit value factor, which was also used in CTLA analysis, is the cost of replacing trees, presented in £/cm2 of trunk diameter.

The CTI rating for Bexhill was 100%. In actuality therefore, the survey concentrated on accessibility, functionality, appropriateness and life expectancy.

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 often have to be managed for safety and are frequently crown lifted or 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 so tend to have a 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 with less than 100% exposure to light. 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 factors were 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.

Life expectancy 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

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