VALUING CRANBROOK'S URBAN TREES

Foreword

When asked, many Cranbrook residents would agree that one of the most attractive aspects of the town are those areas represented by the country park, the nature reserve and the ecology park, which flow through the urban landscape affording recreation space.

Visually, by retaining many of the ancient hedgerows and veteran trees, particularly along the water features and riverbanks, a green and calm environment is created, supplemented by new planting along the main road arteries, in and around the children's play parks and other open spaces. Trees play a vital role in the visual landscape, and importantly, in modifying and stabilising the ecology of the countryside, in ways not always obvious to a casual observer.

The hedgerows and tree canopy provide a habitat where micro-organisms and insects thrive, supply pollen, blossom and berries, food for a wide variety of resident and migratory birdlife, and allow for nesting sites during the breeding season. Protection, hibernation and nesting sites for dormice; navigation highways, and roosts for bats; and control and protect precious river and stream courses, which in themselves nurture a variety of habitats for wildlife, from kingfishers to newts. Equally important is the carbon sequestration capability ('fixing of carbon in natural fabric of the wood as a function of their respiratory system') as a fundamental factor in allaying the effects of manmade climatic variation on a worldwide scale.

Every tree matters, and they always will.

Simply appreciating and admiring our existing 'great trees' is laudable, but in itself is not enough. Cranbrook aims to be proactive in enhancing the landscape by understanding, educating, and engaging its citizens – for such we are – in actively becoming involved with various projects and tree planting initiatives in our country parks and immediate environment. When almost one-third of our tree cover is provided by Ash trees, vulnerable to Ash dieback, we must actively combat their possible loss by diversifying, enhancing the species mix, and planting now.

It is everyone's future, after all, and we can all play our part.

Councillor Barry Rogers,

Cranbrook
Town Council

Background

The Great Trees in the Clyst Valley is a partnership project to encourage the public to explore, record and restore the heritage of trees in fields, hedges, parks and orchards across parishes in the Clyst Valley of East Devon. The partnership includes Devon County Council, Devon Gardens Trust, East Devon District Council, Cranbrook Town Council, Environment Agency, E-on, Heritage Lottery Fund, National Trust, Parishes Together Fund and Woodland Trust.

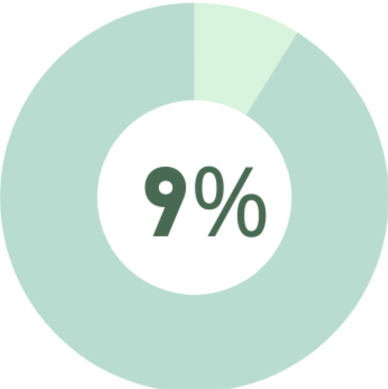
Treeconomics is a social enterprise, with a mission to highlight the benefits of trees and woodlands. Treeconomics develops projects with landowners, communities, academics and other stakeholders to quantify and value trees, green infrastructure and natural capital. Together we deliver sustainable urban forest management plans, projects and consultancy that aim to improve our environment.

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

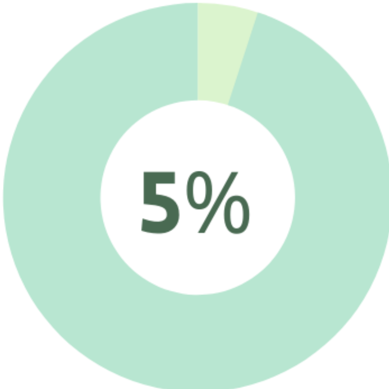
Figure 1: Cranbrook Country Park

THE STRUCTURE OF CRANBROOK'S URBAN FOREST

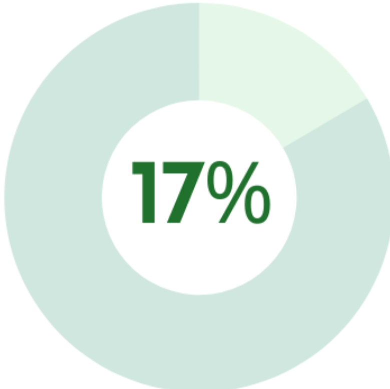
Tree Cover



Shrub Cover



Leaf Area

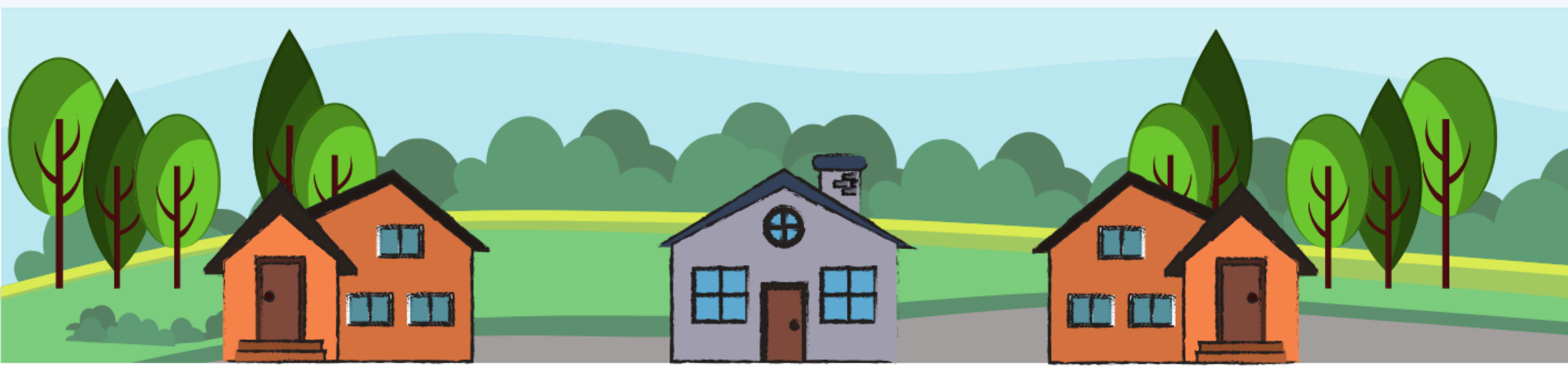


ASH

FIELD MAPLE

OAK

Most Common Tree Species



@CLYSTGREATTREES

THE BENEFITS OF CRANBROOK'S TREES

£16,700
Carbon Sequestration Per Year

£6,400
Pollution Removal Per Year

£6,000
Avoided Runoff Per Year

£548,000
Total Carbon Storage

£57.8 MILLION
Amenity Value (CAVAT)

@CLYSTGREATTREES

Executive Summary

The trees in Cranbrook's parks, gardens, open spaces, woodlands, streets and waterways are collectively described as the 'urban forest'. This report provides a comprehensive picture of the structure and value of Cranbrook's urban forest. It is a detailed study undertaken using i-Tree Eco.

An unstratified[1] i-Tree Eco random sample exercise was carried out with 208 randomly allocated tenth of an acre plots across Cranbrook. This assessment provides a quantitative baseline of the air pollution, carbon storage, carbon sequestration, stormwater benefits and amenity value of the entire tree resource in Cranbrook, accounting for the trees on both public and private land.

Figure 2: Volunteers undertaking tree surveys in Cranbrook

[1] It's important to understand that although this project was unstratified, there is a distinction between the urban and the country park areas of Cranbrook. The former already has a number of non-native species whereas the rural areas have a typical mix of native species. Post stratification analysis of the data could make an interesting future research project.

Acknowledgements

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dgt Devon Gardens Trust

East Devon District Council

Environment Agency

Heritage Fund

e.on

National Trust

Parishes Together Fund

Woodland Trust

Cranbrook Town Council

Project Volunteers:

Jane Bateman, Jeremy Bunting, Richard Dade, Simon Foulds, Naomi Palmer, Erin Reardon, Councillor Barry Rogers, Griselda Shipp, Teresa Sullivan.

Finally, we wish to thank all landowners and members of the public who kindly allowed access to their properties for the collection of the crucial field data. This led to several great conversations, which demonstrated the appetite of the community for more trees in Cranbrook.

Volunteer Perspectives

Griselda Shipp

“After a few years volunteering with countryside management organisations and now working as a ranger myself, I couldn't pass up the chance to get involved with this project that was right on my doorstep! The i-Tree training course was informative and covered the surveying techniques in-depth. Once out in the field, it was a chance to put our new skills to the test, and the brambles, banks, ditches and nettles definitely made locations somewhat more of a challenge! I thoroughly enjoyed taking part in the project and would love to see an increase in tree cover across Cranbrook as a result of this study.”

Naomi Palmer

“Being part of the group surveying local trees and learning more about trees in general was a very interesting experience. Ultimately, the project will have a positive impact on biodiversity and on quality of life in my own neighbourhood and it has been a privilege to have been a small part of it.”

Erin Reardon

“I really enjoyed volunteering with the i-Tree Treeconomics project in Cranbrook. It was gratifying to be able to contribute my time to a project with such potential to contribute to the local community. At the same time, I have learned new skills, spent time outside and met & worked alongside a great team of people. I hope the information that we have gathered will become a good baseline for monitoring and improving the Cranbrook treescape and ecosystem services in years to come.”

Key Findings - Cranbrook Headline Figures

Number of Trees (estimated)	6,991	
Tree Cover	8.9%	
Shrub Cover	5.4%	
Total Canopy Cover (tree + shrub)	14.3%	
Most Common Species	Ash, Field maple, English oak	
Amenity Value (CAVAT)	£57.8 million	
Replacement Cost	£4.8 million	
Carbon Storage	2,165 tonnes	£548,000
Pollution Removal (per annum)	949 kg	£6,441
Storm Water Alleviation (per annum)	1,681 m^3	£6,020
Carbon Sequestration (per annum)	66 tonnes	£16,700
Total Annual Benefits	**£29,161**	

Table 1: Headline Figures (i-Tree Eco sample survey).

Notes on Headline Figures

Total number of trees measured: This is calculated using an extrapolation across the entire area of Cranbrook from the initial trees measured during the sample plot survey. For further details see the methodology section below.

Canopy Cover: The area of ground covered by leaves when viewed from above (not to be confused with leaf area which is the total **surface area** of leaves or canopy cover, this also includes shrubs).

Capital Asset Value for Amenity Trees (CAVAT): A valuation method developed in the UK to express a tree's relative contribution to public amenity and its prominence in the urban landscape.

Replacement Cost: 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.

Pollution removal: This value is calculated based on the UK Social Damage Costs (UKSDC), these are a set of monetary impact values per tonne of emission. Cranbrook has been classified within the 'Transport Urban Small' category. Where UK Social Damage Costs are not available, US Externality Costs (USEC) have been used, these are similar, and aim to provide a cost for the associated consequences of pollutants. Pollutant costs applied are as follows; £0.98 per Kg (carbon monoxide - USEC), £0.43 per kg (ozone - USEC), £8.34 per Kg (nitrogen dioxide - UKSDC), £6.27 per Kg (sulphur dioxide - UKSDC), £152.69 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, which is then re-evaporated after rainfall events. The value is based on South West Water's volumetric charge of £3.58p per cubic metre and includes the cost of avoided energy and associated greenhouse gas emissions.

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 Department of Energy & Climate Change (DECC) figures of £69 per metric ton for 2020.

Data processed using i-Tree Eco Version 6.0.16.

CONTENTS

INTRODUCTION

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 towns and cities, to green infrastructure and to the wider urban ecosystem. Trees provide a 'sense of place', reduce extremes of high temperature in urban areas, improve air quality and act as a carbon sink. Yet, trees are often overlooked and undervalued. The tree benefits measured in this study are summarised in Table 1 (above).

Trees provide numerous socio-economic benefits to our communities. Understanding and valuing these allows us to make more informed planting and management decisions for the benefit of current and future generations.

About Cranbrook

Cranbrook is a new town development in East Devon. It is situated near the city of Exeter, within the upper catchment of the River Clyst amongst the tributaries of the Crannybrook, Rockbeare Stream and Southbrook. The development currently consists of 2,000 properties[2] with planned expansion to 6,550 by 2026[3]. The area was previously agricultural land, which has been developed over time to create a new community in a way that encourages sustainability and minimises carbon emissions.

Local Authority figures estimate Cranbrook's population at approximately 5,000 and expect it to grow to over 18,000 by 2030[4]. As Cranbrook becomes more densely built-up and the demand for housing increases, competition for space will inevitably grow and the urban forest will become an ever-more valuable resource. If Cranbrook is to retain and improve their leafy heritage, there is a well-understood need to protect and manage the established trees in the area, whilst continuing to plant the right tree in the right location.

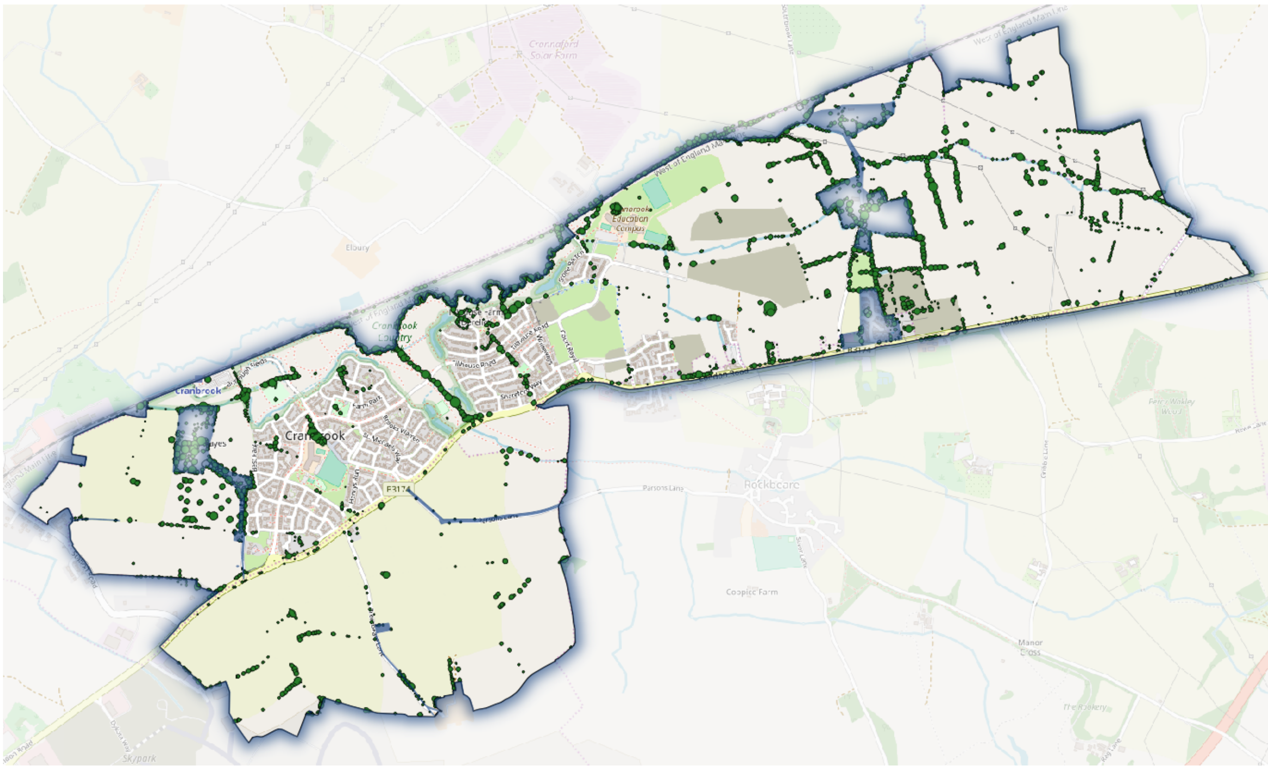


Figure 3: Map of Cranbrook. Its existing canopy cover of 14.3% is represented by the dark green circles.

Aims of the Study

1. To achieve greater canopy cover in the urban realm – the right trees, of the right type, in the right place.

2. To understand the impacts of ash dieback in Cranbrook and the wider countryside, for example, on stormwater control.

3. To up-skill a cohort of Cranbrook volunteers to become advocates to achieve goal 1, and as tree wardens, help the Town Council to nurture trees in public spaces.

We're in a climate emergency. Fortunately, nature has invented something that sucks up carbon dioxide, and gives out oxygen, something we humans find irresistible! Across the expanding town of Cranbrook the tree canopy cover is presently about 14%. That's not enough. The huge metropolis of Manchester is aiming for 30% canopy cover. Our hope is that the results of this work can be used:

1. To inspire everyone and begin to demonstrate how 30% is achievable and will bring great benefits to people and the environment.

2. To secure commitment from all to achieve 30% and agree an action plan to get us there.

METHODOLOGY

In order to gather a collective representation of Cranbrook's urban forest across both public and privately held land, an i-Tree Eco (v6) plot-based assessment was undertaken. 208 randomly allocated plots of 0.04ha (400m^2) in area were surveyed, representing 1.6% of the total survey area (of 536ha). This equates to 1 plot every 2.6ha. For comparison with other i-Tree Eco studies, please see Table 2 (below). Random plot selection ensures that trees on private land are included in the assessment. The data collected for these plots is then extrapolated to represent the whole of the study area.

The following information was recorded for each plot:

Plot Characteristics

Land use, Ground cover, % Tree cover, % Shrub cover, % Plantable space, % Impermeable surface.

Tree Characteristics

Tree species, Shrub species (if known), Height (metres), Trunk diameter at breast height (DBH), Canopy spread, Health and fullness of the canopy, Light exposure to the crown, Distance and direction to the nearest building, and Safe useful life expectancy (SULE).

This data was collected by a team of trained volunteers and arboricultural professionals between July and October 2019. Due to the nature of the sampling method, 210 plots were created for the project. This allowed for the eventuality that up to 10 plots may be inaccessible whilst still maintaining a statistically robust estimate of the urban forest. In total only 2 of the target 210 plots had access restrictions and were therefore not surveyed. These inaccessible plots represent less than 1% of the overall total. A total of 208 plots were included in this study.

Study Location	Plots per area
Cranbrook	1 plot per 2.6 ha
Petersfield	1 plot per 2.7 ha
Torbay	1 plot per 26 ha
Inner London	1 plot per 155 ha
Outer London	1 plot per 245 ha

Table 2: Comparison of plots per area in different i-Tree study locations.

Data Limitations

While trees provide a plethora of benefits, the figures presented in this study represent only a portion of the total value of Cranbrook'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 a conservative estimate.

Furthermore, the methodology has been devised to provide a statistically reliable representation of Cranbrook's urban forest in 2019-2020. This report is concerned with the trees and shrubs within Cranbrook. 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 or street) is required, further survey work should be carried out.

'The first step in reincorporating green infrastructure into a community's planning framework is to measure urban forest canopy and set canopy goals'

- James Schwab

RESULTS AND ANALYSIS

Figure 4: Cranbrook's Green Space

Structure and Composition

Ground Cover

Ground cover in Cranbrook (as measured using i-Tree Eco) consisted of approximately **82%** permeable 'green space', such as grass and soil. Apart from a very small percentage (0.6%) 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 can contribute to a general heating of the urban environment. The amount of these surfaces will increase due to the ongoing housing development planned for Cranbrook.

82% of Cranbrook's ground cover is green space.

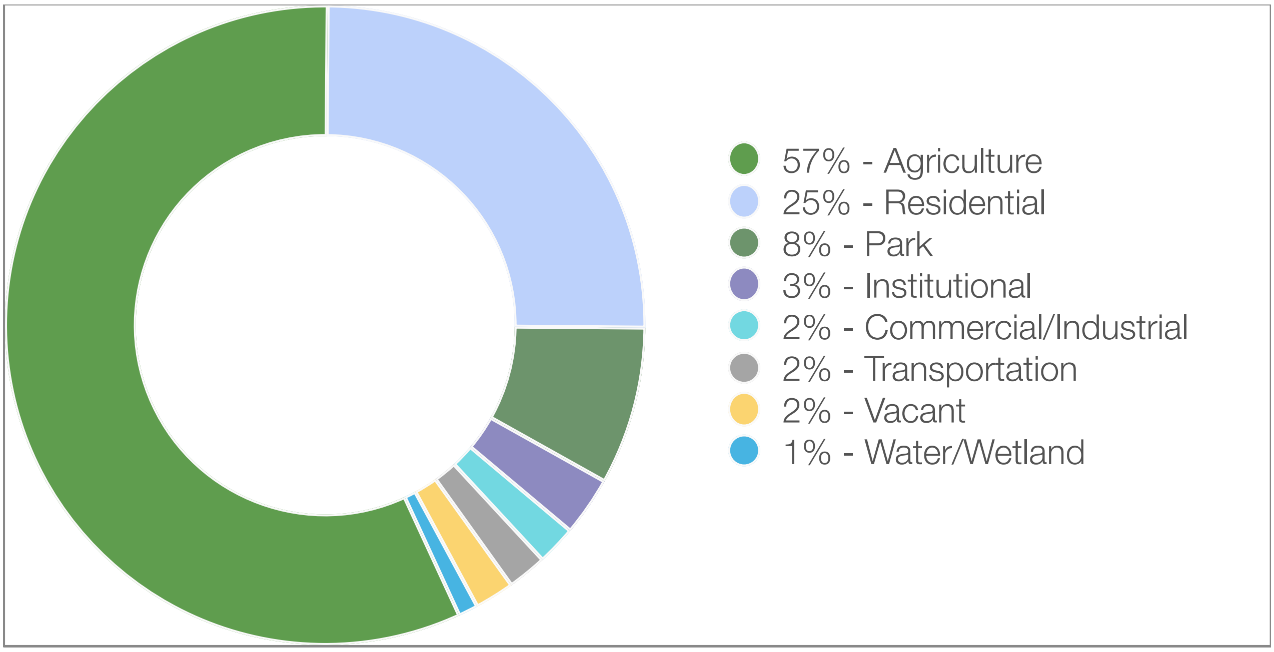
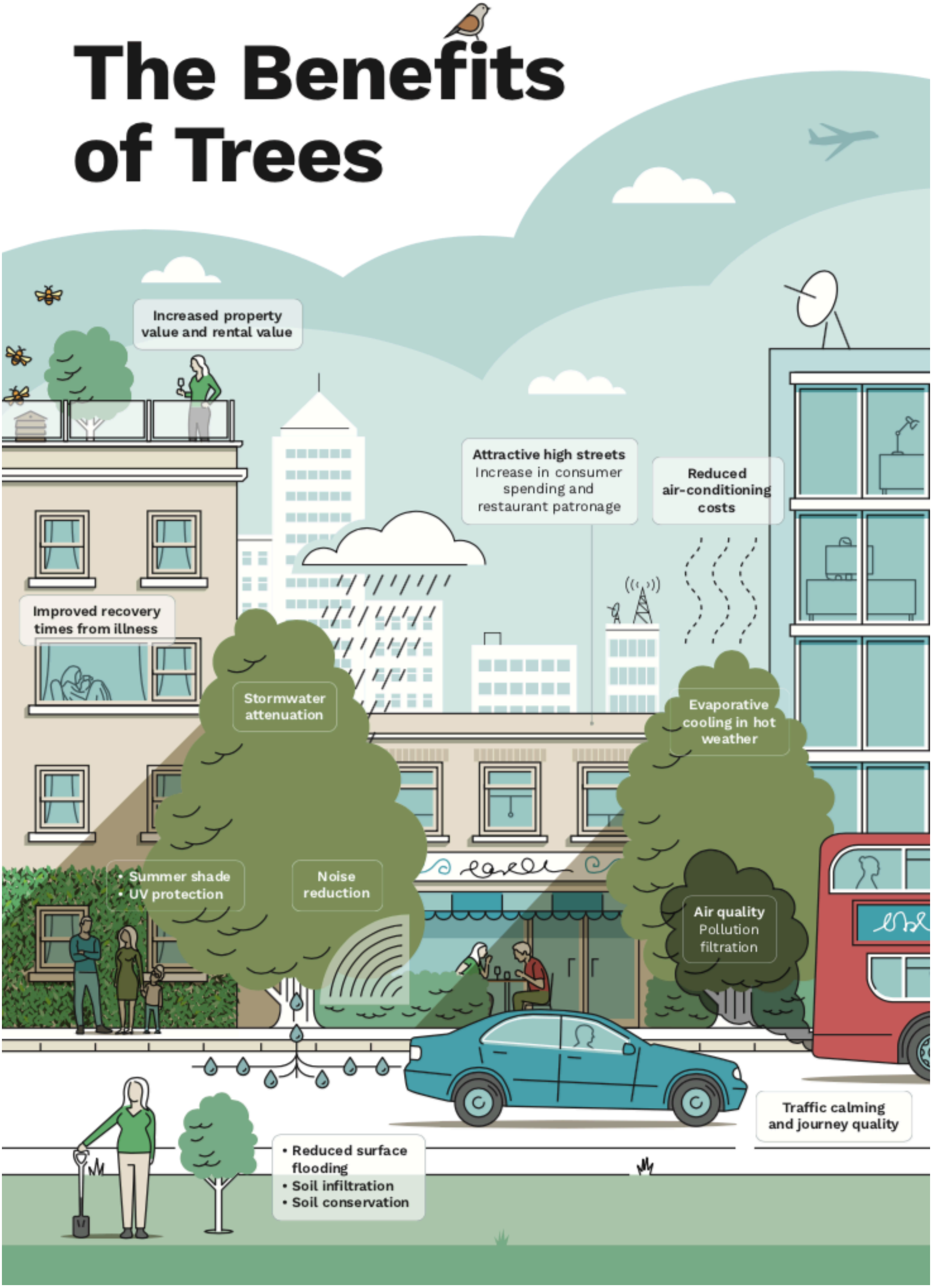
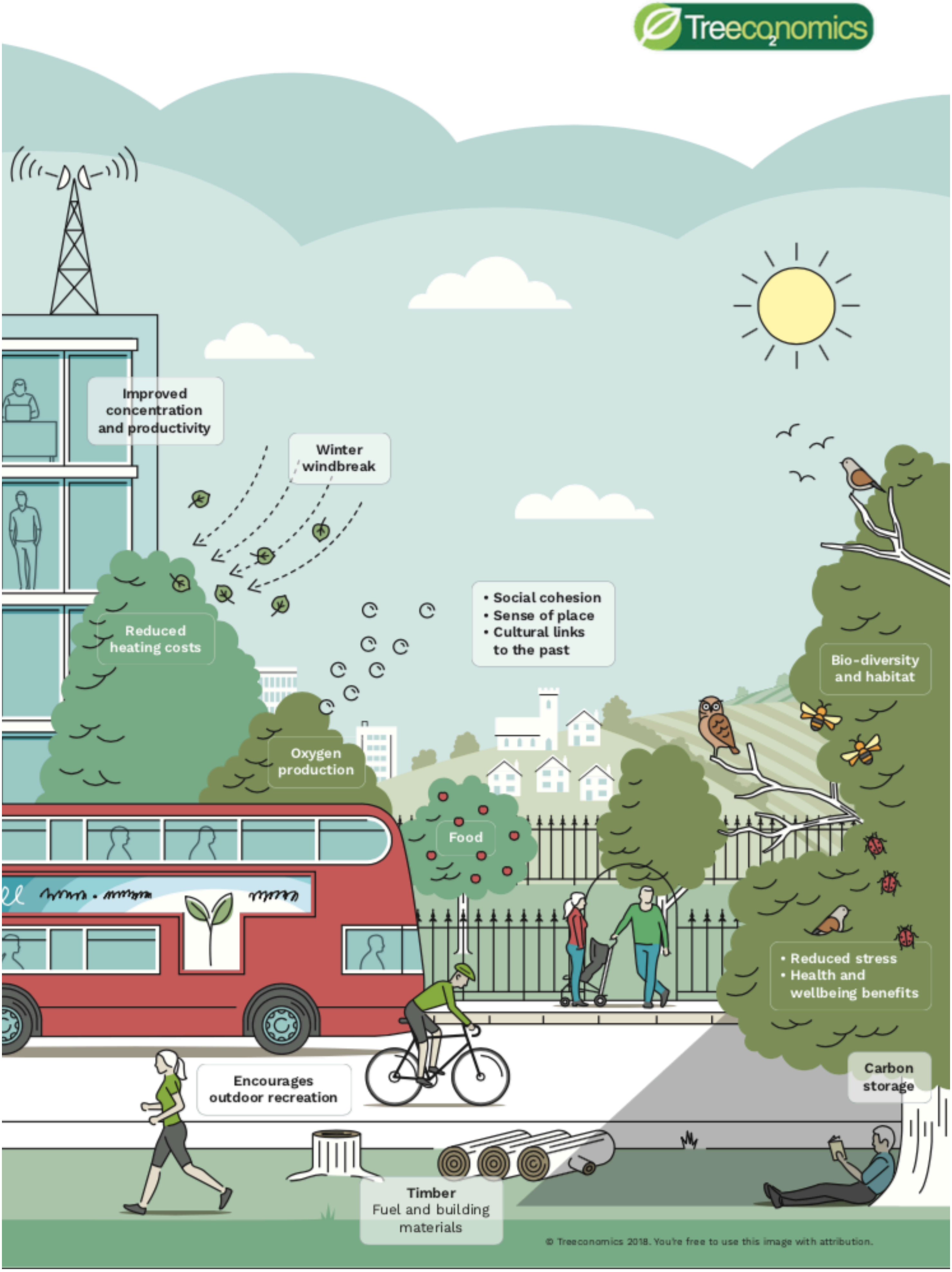


Figure 5: Land use across Cranbrook (i-Tree Eco sample survey).

The Benefits of Trees




Treeconomics
Improved concentration and productivity
Winter windbreak
Reduced heating costs
Oxygen production
• Social cohesion
• Sense of place
• Cultural links to the past
Food
Bio-diversity and habitat
• Reduced stress
• Health and wellbeing benefits
Carbon storage
Encourages outdoor recreation
Timber
Fuel and building materials
© Treeconomics 2018. You're free to use this image with attribution.

Tree Population and Tree Density

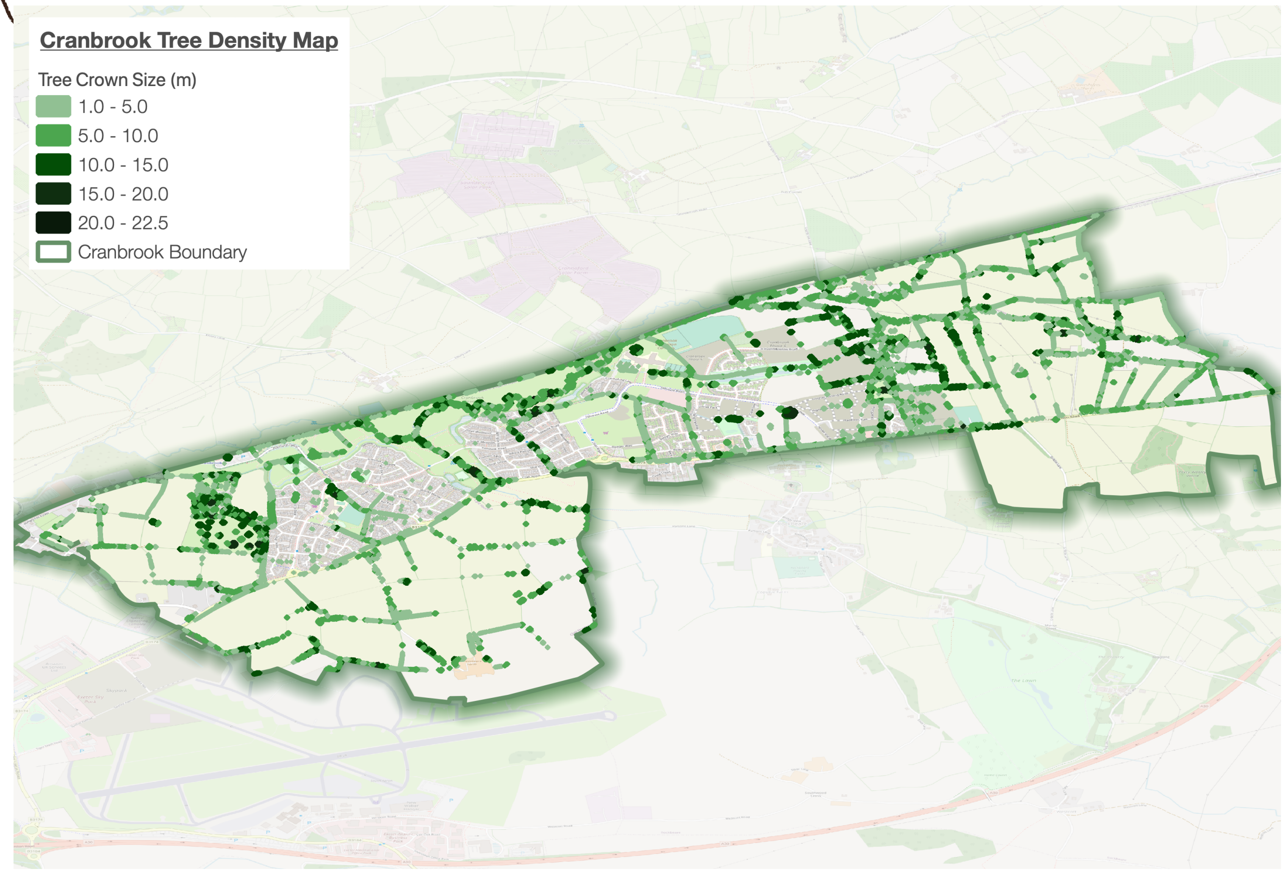


Figure 6: Tree Density across Cranbrook

Across Cranbrook there are an estimated **6,991 trees**. The trees that make up this urban forest are situated on both public and private property.

Tree density across Cranbrook is 13 trees per hectare (ha). Roughly speaking, this equates to around 1.4 trees per person in Cranbrook. It is difficult to compare this average density of trees with other regions as Cranbrook is a 'new town' with continuing development. However, for future aspirations, 58 trees per hectare is the current UK average for towns and cities[5].

[5] Britt and Johnston 2008

26 tree species recorded across Cranbrook

Tree species composition is an extremely important metric to consider for the sustainable management of the urban forest.

A varied species palette does not only improve the aesthetic of (and potentially define) a space or place, but it will also increase the resilience of the urban forest to the threat of invasive pests and diseases, and the challenges of climate change. This increased resilience will of course also benefit the largest stakeholders in Cranbrook's Urban forest; its residents.

In total, **26** tree species were recorded in the i-Tree Eco sample survey.

While these tree species provide a good representation of those most frequently encountered across Cranbrook, it is worth noting that, as a sample survey, the number of species recorded is not the absolute total number of species that would be found across the area.

The three most common species of trees across Cranbrook are **Ash** (*Fraxinus excelsior*) at 30% of the tree population, **Field maple** (*Acer campestre*) at 16%, and **English oak** (*Quercus robur*) at 11%.

Cranbrook's species distribution is illustrated in Figure 7 (overleaf).

Reviewing the species composition enables a cohesive and planned approach to tree planting across both public and privately owned space. This approach allows for enhancement of the tree stock to ensure that there is not over-reliance in a single species or genera, for example.

Planting on private estates is more difficult to influence and so a knowledge of the overall tree species composition can help in selecting or suggesting species.

Across Cranbrook, the ten most common species account for 88% of the total population

Tree Species Composition

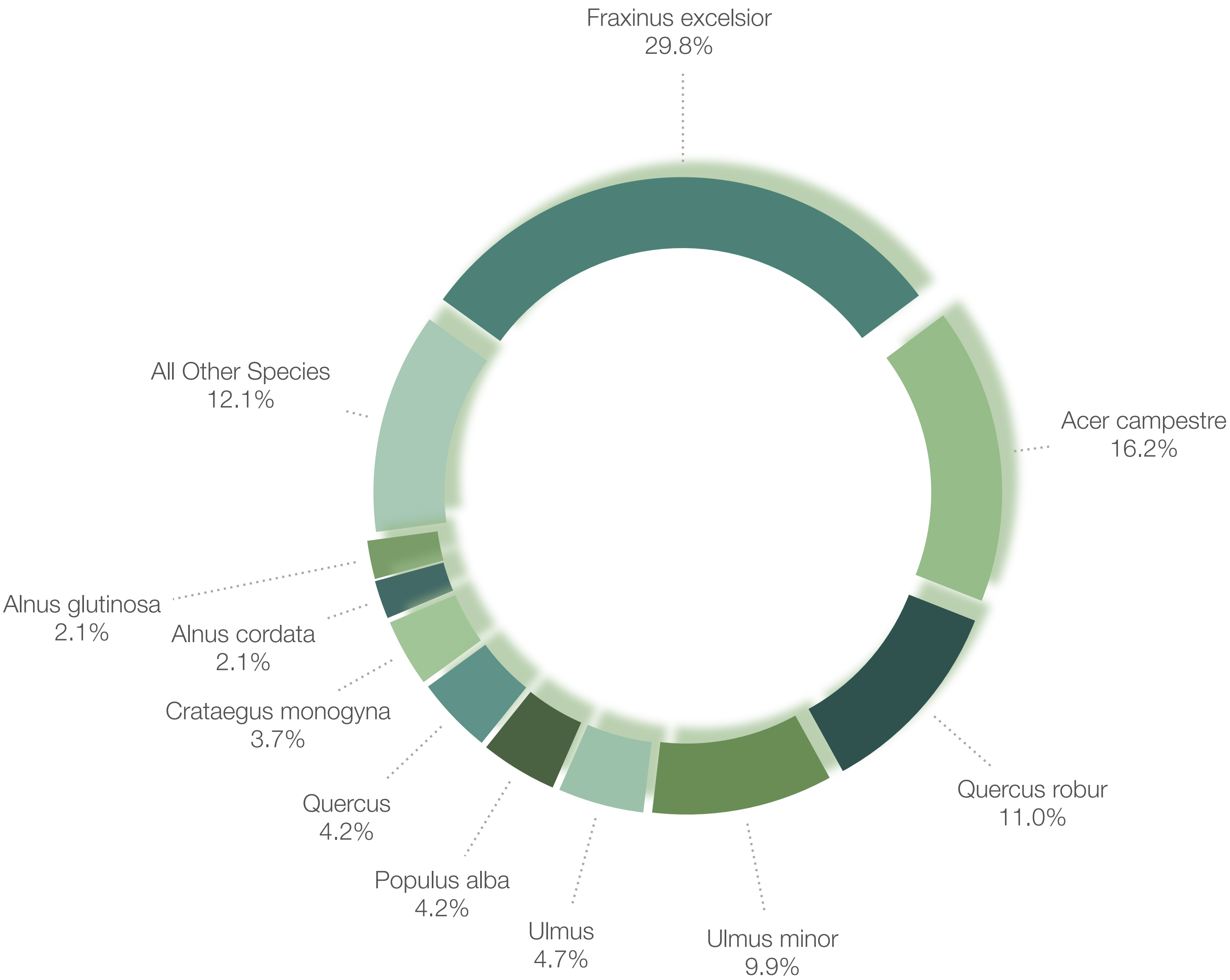


Figure 7: The most common tree genera in Cranbrook (i-Tree Eco sample survey).

"In a forest of a hundred thousand trees, no two leaves are alike. And no two journeys along the same path are alike." — Paulo Coelho

Tree Size Distribution

Size class distribution is another important factor in managing a sustainable tree population. This will ensure that there are enough young trees to replace those older specimens that are eventually lost through old age or disease[6].

Figure 8 (below) illustrates the size range of the ten most common trees across Cranbrook. The sizes are taken from measurements of the tree stem diameter at breast height (DBH).

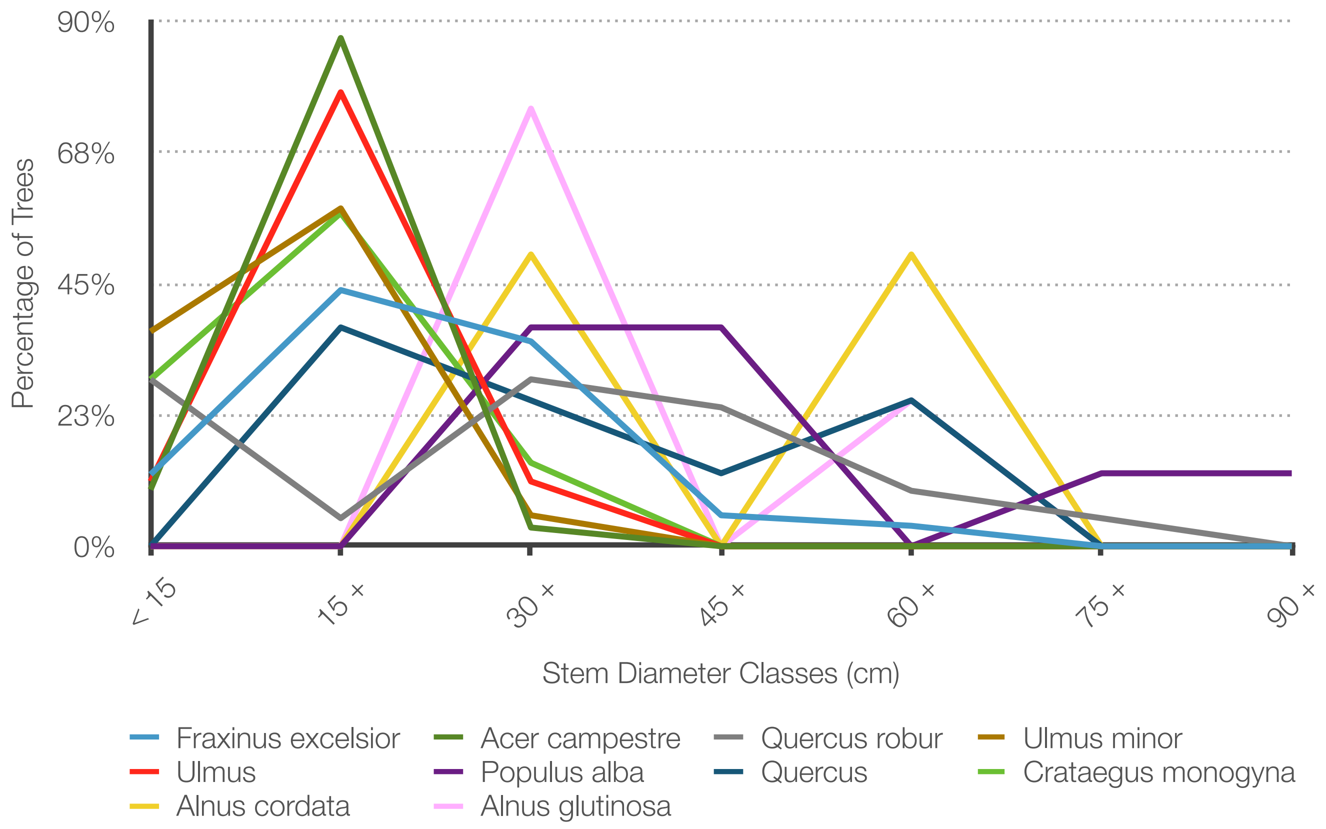


Figure 8: Tree size class distribution (i-Tree Eco sample survey).

The top ten species within Cranbrook represent **88%** of the total population. Of these top ten species of trees, 13% have a DBH less than 15 cm, 73% have a DBH between 15cm and 60cm with the remaining 14% being over 60cm DBH.

[6] Lindenmayer, Laurance and Franklin (2012)

The majority of all trees within Cranbrook are within the lowest size categories, with around 49% of the trees recorded having a DBH of less that 30cm, whilst around 24% of the trees have a DBH less than 15cm.

Despite being a 'new town' this compares favourably with cities and towns in other regions of England where the Trees in Towns II survey found that on average only 10-20% of trees have a DBH that is greater than 30cm[7] .

Trees in the 90+cm DBH class represent the lowest percentage. To maintain a level of mature larger trees, a proactive approach will be required to manage the trees currently in the 65 cm DBH band to ensure a suitable proportion of these trees survive and thrive to attain larger sizes.

Large, mature trees offer unique ecological roles not offered by smaller or younger trees.

[7] Britt and Johnston, 2008

Canopy Cover and Leaf Area

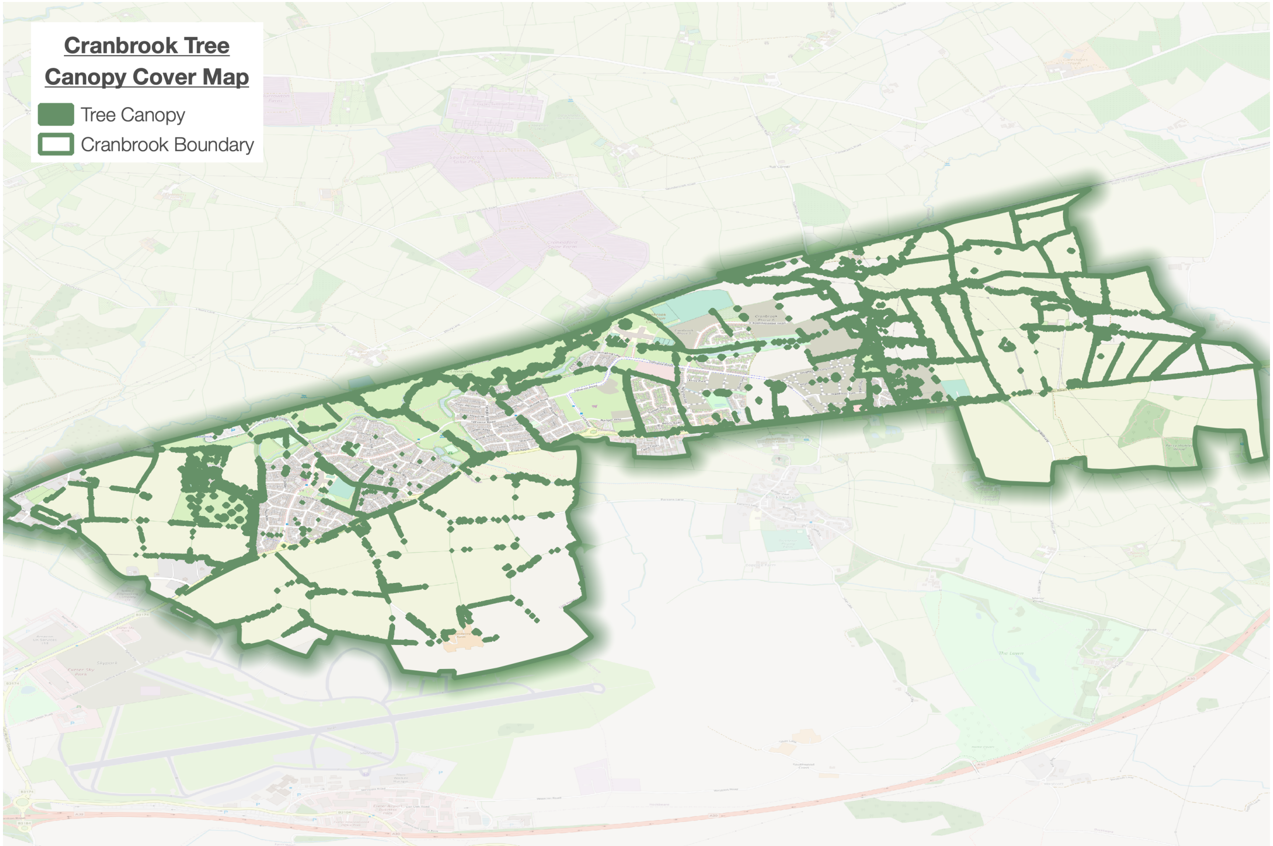


Figure 9: Canopy cover across Cranbrook calculated using BlueSky's National Tree Map (NTM).

Note: This i-Tree Eco study has a slightly larger boundary of Cranbrook than the BlueSky NTM canopy imagery.

Canopy cover (also referred to as tree canopy cover, urban tree cover and urban canopy cover), can be defined as the area of leaves, branches, and stems of trees covering the ground when viewed from above.

Canopy cover is a two dimensional metric, indicating the spread of the crown across an area. It is not to be confused with Leaf Area Index (LAI), which is a measure of the number of layers of leaves per unit area of ground (although canopy cover studies can be used to estimate LAI).

Measuring canopy cover is important because it is an easy-to-understand concept that is useful in communicating messages about our urban forests with the public, policy makers and other stakeholders.

Quantifying tree canopy cover has been identified by many authors (Britt and Johnston, Escobedo, Nowak and Schwab) to be one of the first steps in the management of the urban forest.

Using the BlueSky National Tree Map, Cranbrook's Canopy Cover was calculated to be 12.3% (Figure 9 above). This includes all trees and shrubs over 3m in height.

We can compare BlueSky's canopy cover calculation with the data from this i-Tree Eco study.

i-Tree Eco generates both tree cover and shrub cover, which can be combined to give the total canopy cover of both trees and shrubs. This informative data gives an overview of the total biomass coverage. The i-Tree Eco tree cover for Cranbrook is **8.9%** and the shrub cover is **5.4%**, giving a total canopy cover of **14.3%**. Given the slightly larger area of the i-Tree Eco study, the BlueSky and i-Tree estimations are very close in percentage terms.

Shrubs do make contributions in terms of ecosystem services, and although trees far exceed these, the combination makes up the Urban Forest.

It would be unrealistic to directly compare Cranbrook's canopy cover with other established towns and cities (due to its age and ongoing development), however the UK average stands at 16%. It would be beneficial for Cranbrook to continue to prioritise increasing canopy cover into the future, and this report demonstrates that it would be highly beneficial for Cranbrook to seek to achieve this over the longer term through priority planting schemes and maintenance of the current tree stock in order for it to initially be inline with other UK towns and cities, and in the longer term, achieve their desired target.

Leaf Area and Dominance

Although tree population numbers are a useful metric, when combined with measurements of leaf area, a greater understanding of the dominance that different species play in the delivery of benefits within the urban forest is obtained.

The main benefits derived from trees are directly linked to the amount of healthy leaf surface area that they have.

To demonstrate the dominance of a species, the gross leaf surface area of that species, combined with its abundance in the overall population, indicates its relative contribution of benefits. This is termed the dominance value (DV).

Taking into account the leaf area and relative abundance of the species, i-Tree Eco calculates the DV for each species, ranking the trees in respect of their dominance for the delivery of benefits or ecosystem services.

Figure 10 (below) illustrates the ten most dominant tree species across Cranbrook.

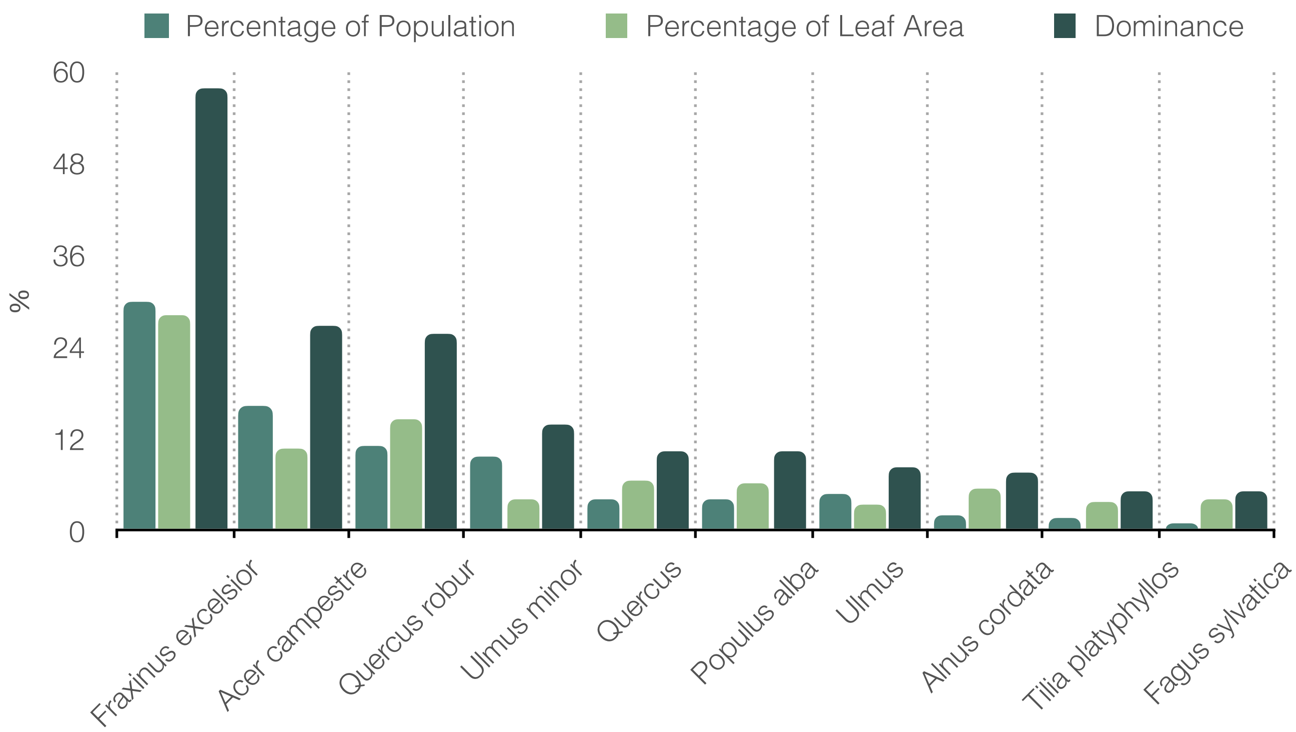


Figure 10: The ten most dominant tree species in Cranbrook. These are the most dominant trees and as a consequence currently the most important in terms of providing benefits (i-Tree Eco sample survey).

Across Cranbrook, **Ash** (*Fraxinus excelsior*), **Field maple** (*Acer campestre*) and and **English oak** (*Quercus robur*), have the largest leaf area and are also the top three most populous trees within the survey, with 29.8%, 16.2% and 11.0% of the population respectively.

The species identified in Figure 10 (above) currently dominate the urban forest structure because they are both the most abundant, and have the largest leaf areas. They could therefore be considered to be the most important in terms of delivering existing benefits. However, future planting programmes should also take into account issues such as climate change, pest and disease and the likely built form of neighbourhoods, streets and new developments.

Leaf area provided by trees for each DBH class are illustrated for Cranbrook in Figure 11 (below).

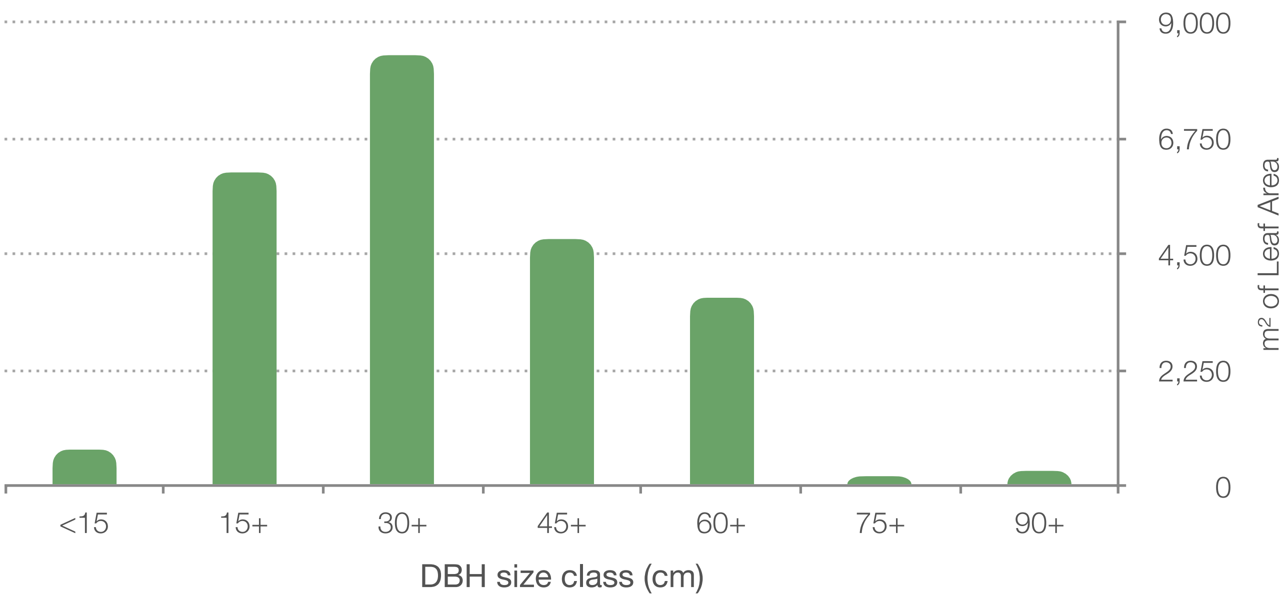


Figure 11: Leaf area (m^2) provided by each DBH class for Cranbrook (i-Tree Eco sample survey).

Larger trees have a greater functional value because they provide increased benefits to the residents of Cranbrook (details of functional values and the resulting benefits are discussed later in this report). It has been estimated in previous studies that a 75cm diameter tree can intercept 10 times more air pollution, can store up to 90 times more carbon and contribute up to 100 times more leaf area than the tree canopy of a 15cm diameter tree[8].

However, Cranbrook has a good proportion of small and medium size trees[9] that, with proper planting and rootable soil volumes, maintenance and management, will in time, continue to grow and develop into larger specimens in time. Thus, they will provide a greater leaf area from a greater proportion of larger trees.

Overall, the total leaf area provided by Cranbrook's trees is approximately 89 ha. This equates to **17%** of the total surface area of Cranbrook.

[8] Every Tree Counts: A Portrait of Toronto's Urban Forest: https://www.itreetools.org/resources/reports/Toronto_Every_Tree_Counts.pdf

[9] When compared to the Trees in Towns II Survey (Britt and Johnston 2008) which found that on average only 10-20% of trees within council inventories had a dbh greater than 30cm.

Tree Diversity

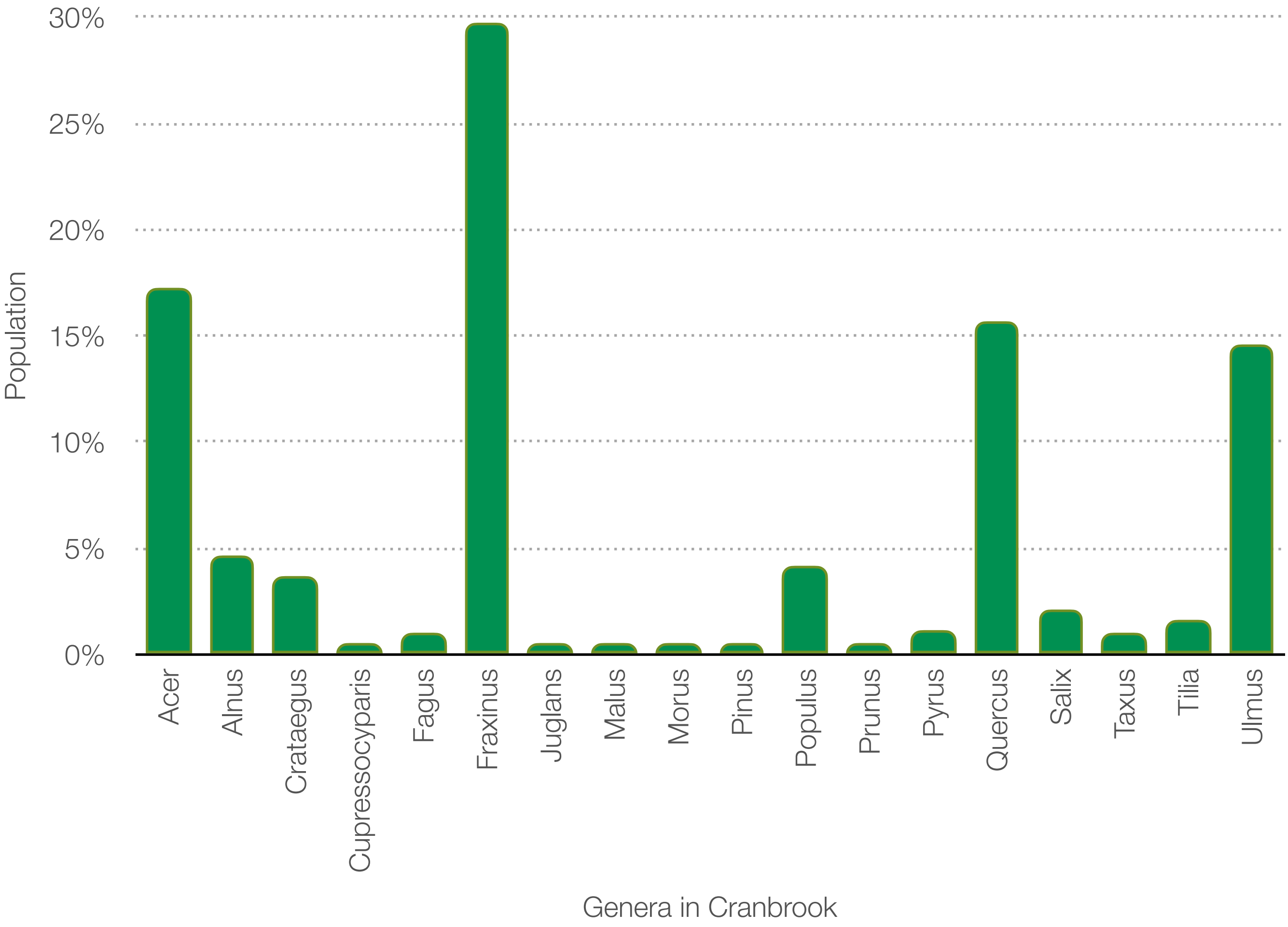


Figure 12: Tree Diversity across Cranbrook (i-Tree Eco sample survey).

Diversity in the urban forest has two main components, the number of species present and the genetic diversity of the individual species present.

Significant diversity of genus, species, size, and age distribution reduces the potential impact from threats such as pest and disease and climate change and increases the capacity of the tree population to deliver ecosystem services.

Species diversity is important because it will influence how resilient the tree population will be to future changes, such as minimising the overall impact of exotic pests, diseases and climate change.

Figure 12 (above) illustrates that the tree diversity in Cranbrook is reliant on four main genera out of a total of 18.

Tree Diversity Literature Review

Barker's 1975 article 'Ordinance Control of Street Trees'[10] provided practical advice and guidance for tree managers to utilise when considering future tree planting and management of inventories. Barker proposed that new planting should be based on a list of selected species following review of the current tree inventory; the key being that scheduled species for planting would represent no more than a 5% density of the population.

Many other authors including Santamour, Kendal and Sjöman have echoed the idea of using benchmarks to guide planting and increase species diversity, however they have examined the evidence and practicalities further.

Following the work of Barker[9], Santamour[11] recognised a tendency of city planners to adopt the vision that no more than 10% of any species should be planted in a given area. Perhaps the vision of tree managers was focussed at the species level. This is where Santamour's work evolved. He noted that this frequently-used 10% rule did not appear to have strong foundations. Santamour proposed a new, more detailed strategy for city planners to apply. He proposed a proportional percentage rule, which stipulates that no more than 10% of any species, 20% of any genus and 30% of any family be planted throughout a city's area. This rule relates to monitoring species diversity, as well as planning future planting carefully based on existing tree stocks.

Santamour's benchmark, which stipulates that no more than 10% of any species, 20% of any genus and 30% of any family be planted throughout a city's area, was widely accepted and considered to be a 'rule of thumb' in order to increase diversity in the urban forest.

Kendal's study[12] concluded that generally urban forests are less diverse than the proposed benchmarks of Barker and Kendal, and therefore applying a 10% maximum limit on the proportion of species within the population would see increases in diversity at the species level. With urban forests generally meeting the genus and family level benchmarks of 20 and 30% respectively, species level remains the key focus.

Sjöman *et al.*[13] conducted a review of diversity and distribution of urban trees throughout 10 major nordic cities. In support of the findings of Sjöman *et al.* in European case studies, Rumble *et al.* in the UK found that all study areas had at least two species which exceeded the 10% population representation benchmark[14]. Given that Cranbrook's three most common species represent 30% (*Fraxinus excelsior*), 16% (*Acer campestre*) and 11% (*Quercus robur*) of the population respectively, it

[10] Barker, 1975

[11] Santamour, 1999

[12] Kendal, 2014

[13] Sjöman *et al.*, 2012

[14] Rumble *et al., 2015*

would be appropriate for the Cranbrook to work towards meeting the initial benchmark of 10%.

The key point stressed throughout Sjöman's study, was the importance of planning. To quote Santamour, there is a need to 'put the right tree in the right place'. Trees selected to simply boost diversity is not the answer; poorly chosen trees may not be suited to site conditions and therefore underperform, ultimately causing a disbenefit to tree management professionals[15].

Cranbrook has a total canopy cover of 14.3%

Increasing diversity would improve resilience to pest and disease outbreaks, as well as our changing climate.

Structure and Composition

Recommendations

The diversity of tree species in Cranbrook is generally low, with the top three species dominating a large percentage of the total poluation, and exceeding the benchmark of 10% proposed by Santamour. Increasing diversity would improve resilience to pest and disease outbreaks. Ash is the most common species (representing just under 30% of the population) across Cranbrook and provides a large amount of the ecosystem services. However, this species is susceptible and at the highest risk of the pest and disease impacts from Ash Dieback.

Tree density in Cranbrook (trees per hectare) is lower than the UK average. Overall canopy cover (trees and shrubs) of 14.3% across Cranbrook is also slightly lower than the UK average of 16%.

There is a disproportionate amount of smaller stature trees to larger trees across Cranbrook. Larger trees (those over 60cm DBH) provide great benefits and return on investment.

Leaf area and canopy cover can be used to indicate relative tree presence or dominance and this spatial analysis is preferable to simply using numbers of trees. This is because it incorporates the area of leaves in the tree canopies, which are the driving force of many tree benefits.

Therefore, it is recommended that:

1. A wide variety of tree species are planted (with due consideration to local site factors) to reduce the over-reliance on key species, bringing the proportions of each species below 10% of the population. In addition, reducing the likelihood and impacts of any given pest or disease outbreak.

2. Protection for existing mature and maturing trees is enhanced, together with increasing the planting of large-stature trees, (where possible) to increase canopy cover and the provision of benefits. This should be targeted to those areas with the least tree cover at present.

3. Cranbrook should set out a strategic plan to reach their canopy cover goal of increasing tree canopy cover on both public and private land. Part of this goal can be achieved by protecting and growing existing trees (see 2 above).

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

- **i. Cranbrook carries out a systematic and thorough inventory of all the trees under council ownership;**

ii. an online ‘WebMap’ is produced to display the current data and illustrate future changes for communication with professionals and the wider community;

iii. a strategic urban forest master plan (with a vision for 2100) is produced setting out how these and other recommendations can be measured, targeted to the areas of greatest impact and need, and implemented. It will also set out criteria for a repeat assessment in 5-7 years to monitor progress.

5. Further investigation is established if there are any barriers to the planting and establishment of tree in areas with the lowest canopy cover.

Ecosystem Services

Air Pollution Removal

Air pollution caused by human activity has become a growing and challenging problem in our urban areas since the beginning of the industrial revolution, initially with the increase in population and industrialisation, and latterly with the huge increase in the numbers of vehicles on our streets. It has resulted in large quantities of pollutants being produced.

The problems caused by poor air quality are well known, ranging from human health impacts to damage to buildings and smog.

Urban trees help to improve air quality by reducing air temperature and directly removing pollutants[16]. Trees intercept and absorb airborne pollutants on their stems, branches and leaves[17]. Although urban trees can decrease the wind speed in towns and cities, they can also produce more turbulence, which helps disperse pollution emitted by traffic, resulting in lower exposure to the general public[18]. In addition, by removing pollution from the atmosphere and dispersing pollution from public areas, trees reduce the risks of respiratory disease and asthma, thereby contributing to reduced healthcare costs[19].

Trees can also indirectly help to reduce energy demand in buildings, resulting in fewer emissions from gas and oil fired burners, excess heat from air conditioning units and reduced demand from power plants.

Annual total pollution removal across Cranbrook is estimated at 949kg.

[16] Tiwary et al., 2009

[17] Nowak et al., 2000

[18] Defra (2018)

[19] Peachey et al., 2009. Lovasi et al., 2008

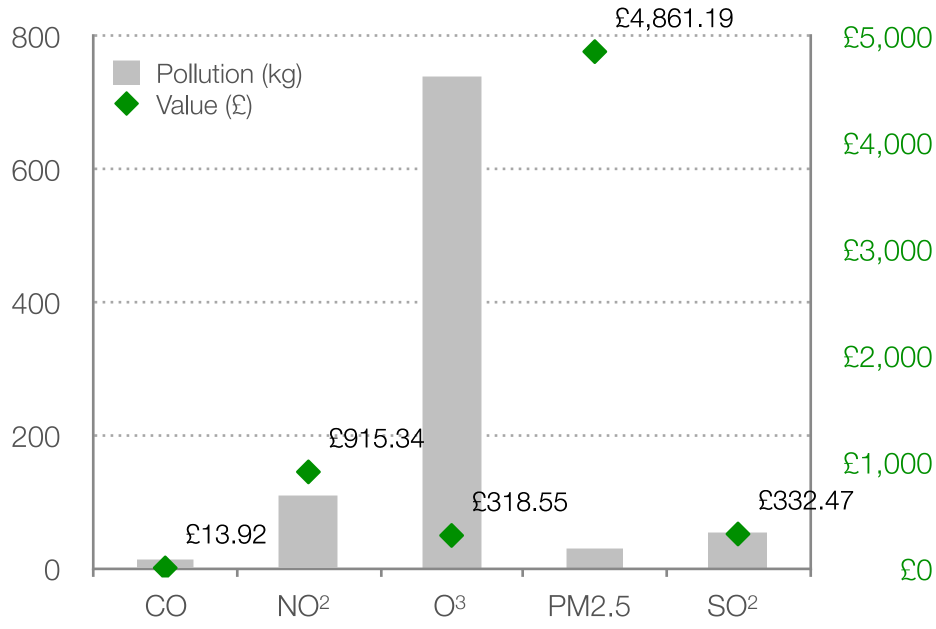


Figure 13: Value of the pollutants removed and quantity per-annum within Cranbrook (i-Tree Eco sample survey). Valuation method's used are UK social damage cost (UKSDC) where they are available - where there are no UK figures, the US externality cost (USEC) are used as a substitution.

Simultaneously to reducing ozone levels[20], a number of tree species produce volatile organic compounds (VOCs) which lead to ozone production in the atmosphere. The i-Tree software accounts for both reduction and production of VOCs within its algorithms. Although at a site-specific level, there may be individual trees which have the potential to cause some ozone production, the overall effect of Cranbrook's trees collectively is to reduce ozone concentrations through a combination of processes including evaporative cooling.

Total pollution removal across Cranbrook (i-Tree sample survey) is estimated at **949kg** or 1.77kg/ha/yr. This is associated with a saving of **£6,441** per year. Total annual amounts and pollution removal values for Cranbrook are shown in Figure 13 (above).

The impacts of trees on Ozone (formed by nitrogen dioxide and sunlight) are greatest, with 740kg filtered from the air every year, with an associated value of over £318.55 per year.

Greater tree cover, pollution concentrations and leaf area are the main factors influencing pollution filtration. Therefore, increasing areas of tree planting could be expected to make improvements to air quality. Furthermore, because filtering capacity is closely linked to leaf area ,it is generally the trees with larger canopies that provide the most benefits.

[20] Nowak and Dwyer (2000)

Carbon Storage and Sequestration

Trees can help mitigate climate change by 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 carbon for decades or even centuries. Over the lifetime of a single tree, several tons of atmospheric carbon dioxide can be absorbed.

Carbon storage relates to the carbon currently held within the trees' tissue (roots, stem, and branches), whereas carbon sequestration is the estimated amount of carbon removed annually. It is interesting to note that net carbon sequestration can actually be a negative value where emission of carbon from decomposition (dead trees) is greater than amount sequestered by healthy trees.

Maintaining a healthy tree population will ensure that more carbon is stored than released[21]. Utilising the timber in long term wood products or to help heat buildings or produce energy will also help to reduce carbon emissions from other sources, such as power plants.

An estimated **2,165 tonnes** of carbon is stored in Cranbrook's trees with an estimated value of **£547,870**. This is equivalent to 4t/ha.

Oak stores the greatest amount of carbon within the urban forest (Figure 14 below), equating to 542 tonnes. Together, the top ten tree species store **92%** of the total.

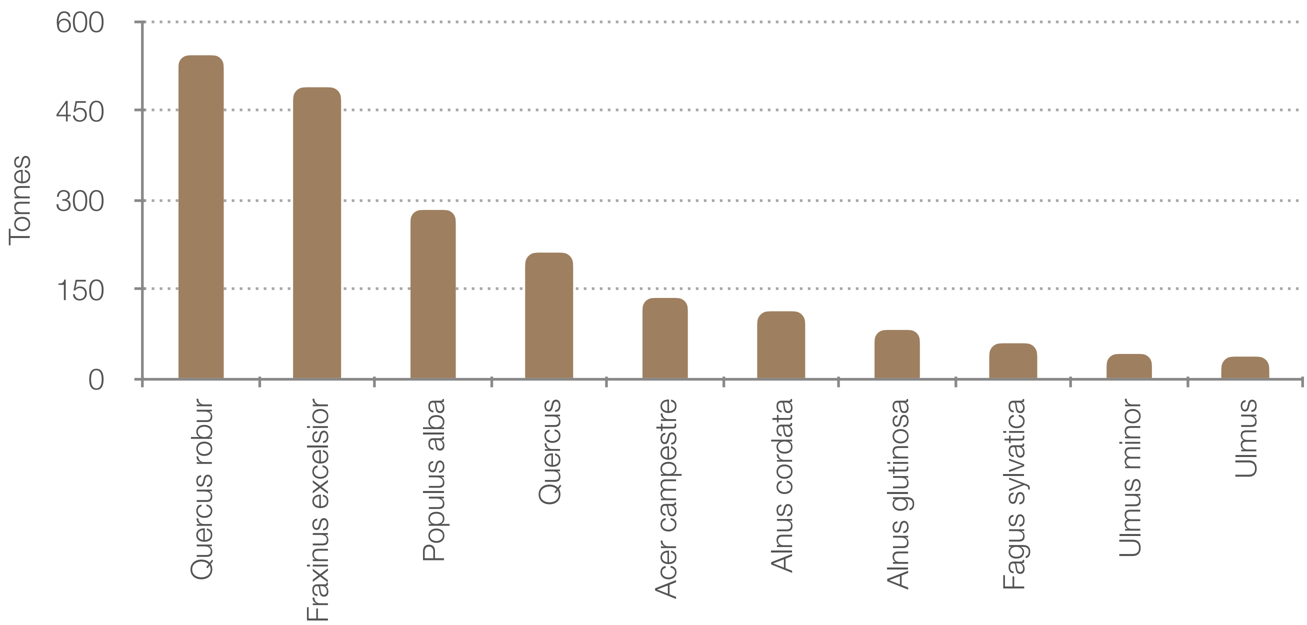


Figure 14: Ten most significant tree species across Cranbrook and the associated carbon storage (i-Tree Eco sample survey).

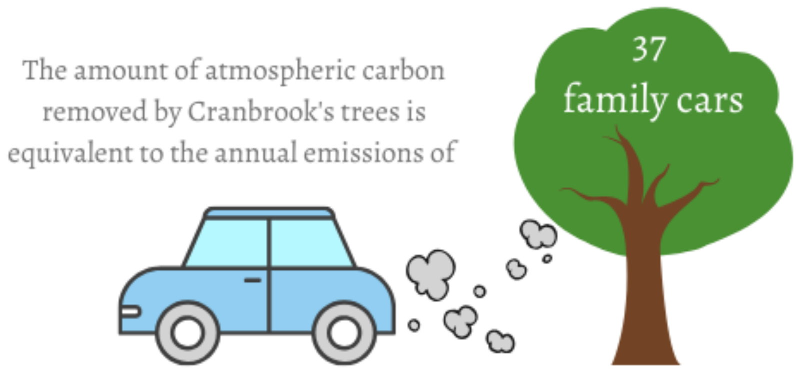
[21] Nowak et al (2002c)

The gross sequestration of Cranbrook's trees is around **66 tonnes** of carbon per year (approximately 0.12t/ha/yr). The value of this sequestered carbon is estimated at **£16,670** per year. This value will increase in a non linear fashion as the trees grow and as the social cost of carbon (its value per tonne) increases.

66
tonnes of carbon are sequestered by Cranbrook's trees per year, equating to an annual value of
£16,670

Across Cranbrook the ash and oak are the most important trees in terms of carbon sequestration, as shown in Figure 15 (below).

Trees also play an important role in protecting soils, which is one of the largest terrestrial sinks of carbon. Soils are an extremely important reservoir in the carbon cycle because they contain more carbon than the atmosphere and plants combined[22].



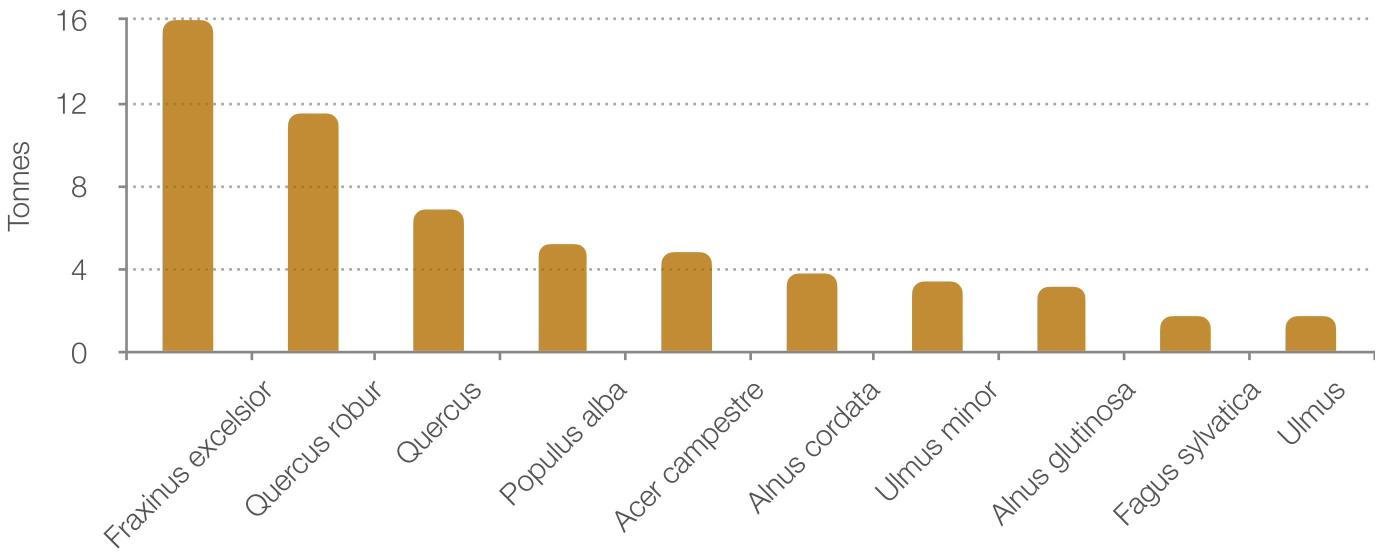


Figure 15: The carbon currently sequestered each year in Cranbrook's urban forest (i-Tree Eco sample survey).

Avoided Runoff and Stormwater Attenuation

Surface water flooding occurs when rainfall runs over land and buildings at such a rate that it is unable to drain away into streams, rivers, drains or sewers. It is therefore distinct from river flooding or tidal flooding where rivers or the sea breach river banks or sea walls and defences. It is estimated that over 5.2 million properties, which represents 1 in every 6 properties, are at risk of flooding in England and that surface water flooding damage costs are over £1 billion every year[23].

Runoff occurs in the built environment from virtually every rainfall event, with streams receiving frequent discharges of polluted runoff from urban surfaces (hydrocarbons, suspended solids and metals etc.).

Trees have the potential to 'capture' an amount of water during rainfall events, which is held in tree canopies. After these rainfall events, moisture is evaporated again into the atmosphere. The cycle may repeat many times but water cycled in this way is diverted and thereby prevented from entering combined sewers. Some of the rainfall will also be directed down the trees' network of branches and stem directly into the soil at the base of tree. This is the way in which trees attenuate or reduce runoff.

The 'value' of this ecosystem service is that if the water is diverted from the combined sewerage system, it does not have to be treated, leading to a very real saving in treatment costs and avoided energy emissions.

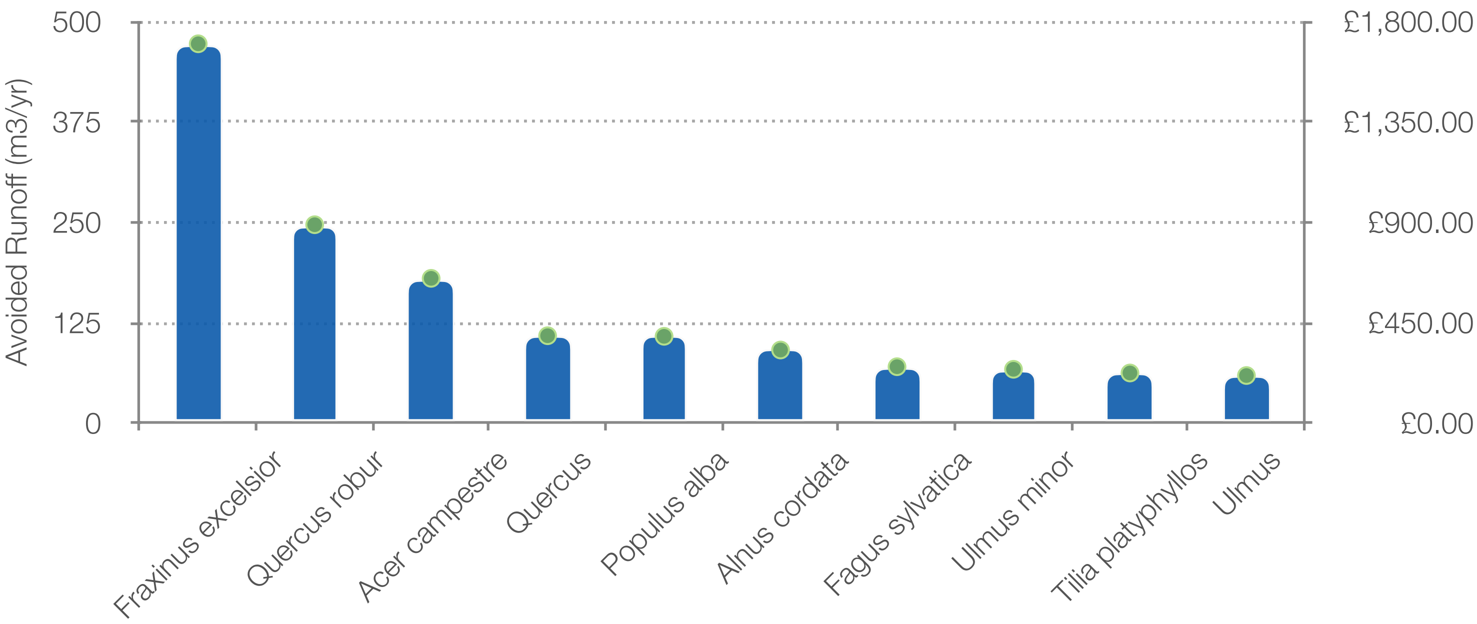
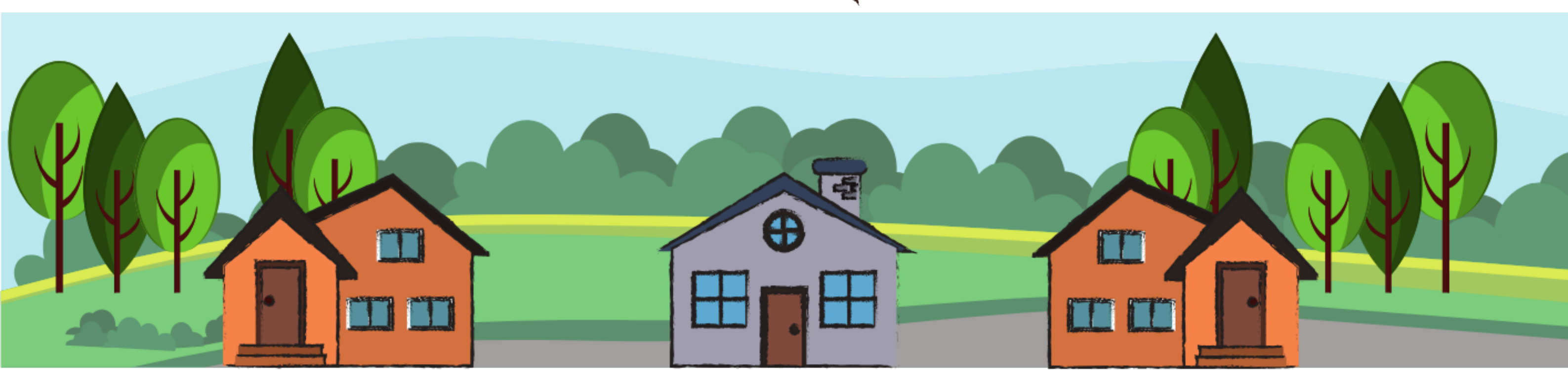


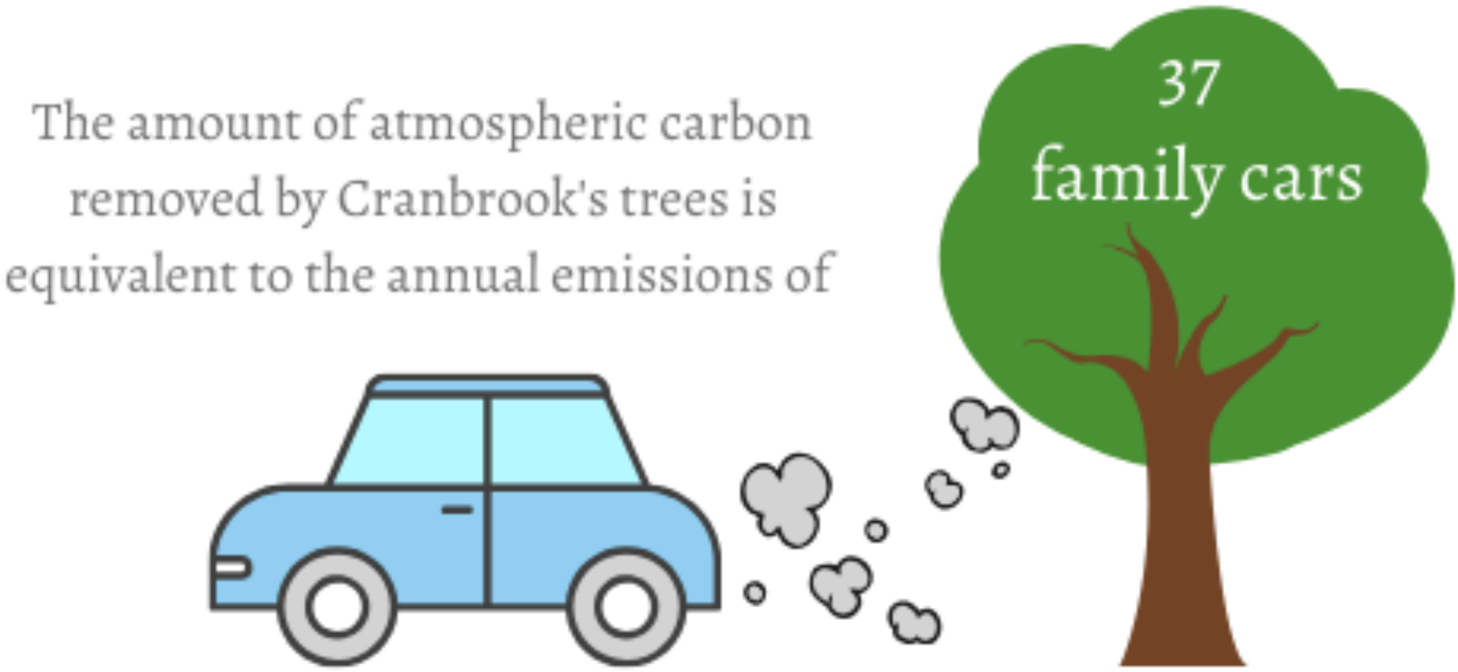
Figure 16: Avoided runoff for the top 10 tree species in Cranbrook

23 Environment Agency, 2009

Cranbrook has an estimated total tree population of **6,991 trees** with a leaf area of some **0.89km²**. The effect of this leaf area is estimated to produce an avoided runoff of nearly **1,700m³** per year. This avoided runoff has a value of over **£6,000** every year.

Figure 16 (above) illustrates the contribution of the top ten tree species across Cranbrook in reducing runoff and the associated value, using the avoided sewage treatment costs and avoided energy emissions.




The amount of atmospheric carbon removed by Cranbrook's trees is equivalent to the annual emissions of
37
family cars

Ecosystem Services

Recommendations

Cranbrook's' trees provide a range of benefits. An identified need, and evidence of their contributions can help maximise these benefits. Trees also need to be healthy and functioning efficiently. Selecting the right species and location will help to enable trees to perform to their maximum capacity. Preferably, the impact needs to quantifiable too.

Therefore it is recommended that:

6. a review is conducted of the 'potential plantable space'. This includes mapping local air quality and social indicators such as the index of multiple deprivation, alongside tree cover, to identify spaces and places where the addition of trees could help improve evenness of canopy cover throughout Cranbrook.

7. areas of most need are identified and targeted to be investigated for tree planting suitability. The results should also be challenged by professionals with local knowledge and experience as there may be 'barriers' (such as under- and over-ground services such as, infrastructure owned by electricity and water companies) to tree planting in the identified areas which will need to be addressed;

8. species are selected that are appropriate to the site to maximise tree benefit delivery and realise the full site potential. It is essential that trees are planted with some level of community engagement if planting initiatives are to succeed;

9. the development of any tree planting programs need to be sustainable and be co-ordinated with other local stakeholders as part of a larger sustainable urban forest masterplan for Cranbrook;

10. develop a WebMap tool for Cranbrook to illustrate the results of this Eco study and enable community engagement with the ecosystem values of urban forest.

Pests, Disease and Tree Health

Pest and Disease Impacts

Pests and diseases are a serious threat to urban forests, with risk exacerbated by our changing climate. The continued importation of trees, particularly large landscape trees, from across Europe and elsewhere is compounded by the ever increasing range of packaging materials used in international trade also increases the risk.

Within living memory we have seen severe outbreaks such as Dutch Elm Disease, which killed approximately 30 million Elm trees in the UK during the late 60's and 70's.

The potential impact of pests and diseases may vary according to a number of factors such as climate and weather, tree health, local tree management, and individual young tree procurement policies. Knowledge of a tree stock's population characteristics enables monitoring of those risks that occur more frequently within a particular tree family, genus or species.

A tree population dominated by few species is more vulnerable to significant impacts from pests and diseases than a population composed of a wider variety. One of the prime objectives of any urban forestry management programme should be to facilitate this resilience through population diversity.

'Ash Dieback poses a threat to 30% of the tree population in Cranbrook. It would potentially cost £1.4 million to replace the affected trees.'

The pest and disease analysis below only incorporates the potential effects from the sample plot data processed though i-Tree Eco.

The i-Tree Eco data can be interrogated to look at the effects of over 30 tree pest and diseases, three of the most significant identified by the council have been reviewed here.

Figure 18 (overleaf) shows how much of the urban forest population may be susceptible to the chosen pathogens.

Figure 19 (also overleaf) illustrates the potential cost of replacing the lost trees following an outbreak of the pathogens investigated. This 'replacement cost' is calculated within i-Tree using the Council of Tree and Landscape Appraisers (CTLA) method, which is adapted for the UK by Hollis (2007) and endorsed by the Royal Institute of Chartered Surveyors.

Figure 18: Potential pest and disease susceptibility (i-Tree Eco sample survey).

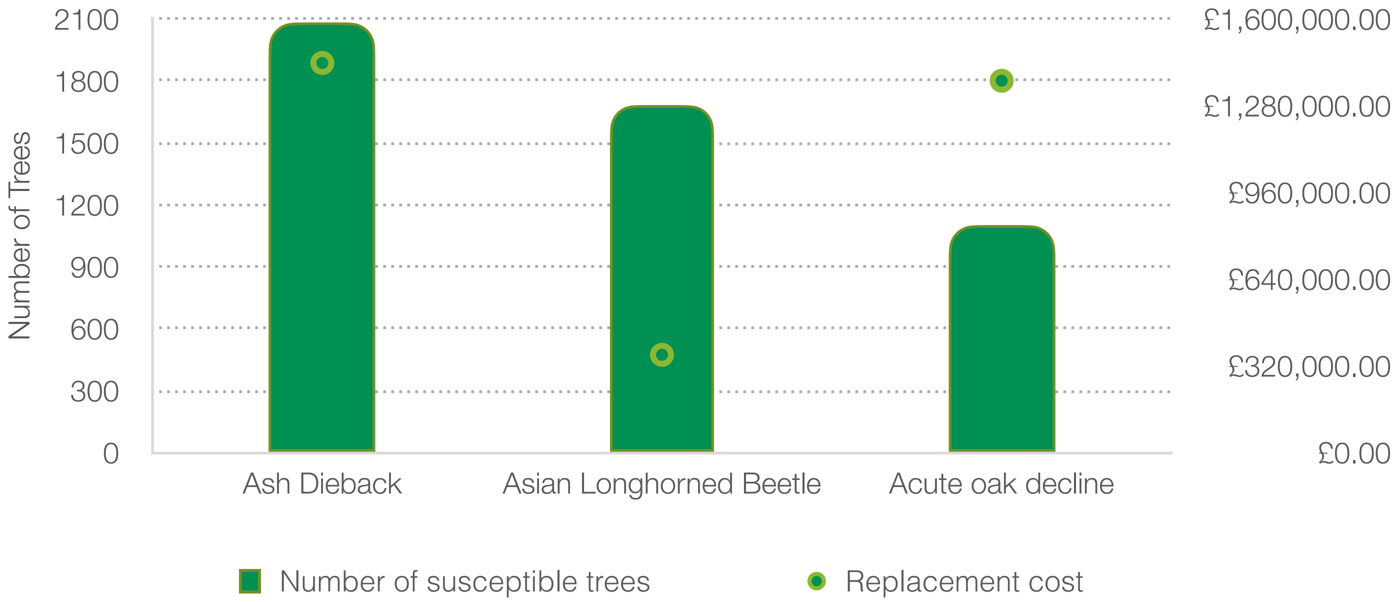


Figure 19: Potential pest and disease impacts. Number of trees susceptible and their replacement costs (i-Tree Eco sample survey).

Ash Dieback (Hymenoscyphus fraxineus)

Hymenoscyphus fraxineus (formally *Chalara fraxinea*) is a “*highly destructive disease*”. This vascular wilt fungus causes the dieback and death of ash trees. Ash dieback is harmless in its native range in Asia, associating with native ash species including *Fraxinus mandshurica*. However, European ash (*Fraxinus excelsior*) has shown to be highly susceptible to the pathogenicity of *H fraxineus*. Whilst thought to have been introduced to Europe in 1992, it was first discovered in the UK at a nursery in Norfolk in 2012.

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[24]. Whilst initially occurring predominantly in ash populations that had been recently planted, by the summer of 2014, infected trees were being found within established woodlands in the wider environment. Forest Research suggest that older trees can resist the fungus for some time, continued exposure along with other pests and pathogens, weakening their health, can cause the older trees to be overcome[25].

Ash Dieback poses a threat to **30%** of Cranbrook’s tree population with around **2,086** susceptible trees.

Ash trees are large in stature and are the most common species within Cranbrook's tree population. These ash trees make substantial contributions to the ecosystem service provision within Cranbrook and the loss of such trees could have a great impact.

The cost to replace the affected trees is estimated to be around **£1.4 Million.**

Asian Longhorn Beetle (ALB)

Asian Longhorn Beetle is native to SE Asia where it is a major problem. The beetle kills a variety of hardwood species, including some of those found within Cranbrook.

To date, the beetle has been found twice in the UK during inspections of incoming packaging in several ports, and a small population became established in Kent in 2012 (although removed by the Forestry Commission and the Food and Environment Research Agency (FERA)).

[24] http://silviculture.org.uk/ash-dieback-disease/

[25] Forest Research, 2020

It is estimated by the United States Department of Agriculture Forest Service[26] that unless the spread of the beetle is contained, the beetle could result in up to 30% tree mortality across the United States.

As the more common families of trees contained within Cranbrook are preferential for the beetle, it is possible that an outbreak could affect **24%** of the tree population - that's **1,684** susceptible trees.

It would potentially cost **£361,000** to replace the affected trees.

Acute Oak Decline (AOD)

There have been episodes of 'acute oak decline' within the UK for almost 100 years, and it is regarded as a complex disorder whereby typically several damaging agents interact. Trees can fail within four to six years of the onset of symptoms. For a tree to become infected, it is usually following some weakening

Conditions that make oak trees susceptible to AOD may be triggered by:

- cycles of foliage destruction (often caused by defoliating insects and powdery mildew), which weaken the tree;
- damage to bark cambium where the phloem and cambium are destroyed (probably caused by insects and bacteria).

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

Typically the infected tree stems (trunks) of oak trees will have "*patches of black fluid weeping from cracks in the bark, which cover rotting tissue*". A presence of key bacteria (*Brenneria goodwinii, Gibbsiella quercinecans Rahnella victoriana* and *Pseudomonas*) along with the two-spotted oak buprestid beetle (*Agrilus biguttatus*) are commonly found in abundance on affected trees.

Once the disease has occurred, generally the infected trees are retained unless there is an imminent concern regarding safety. Due to the close proximity of a high value target i.e. the carriageways within Cranbrook, removals may therefore be necessary. Alternatively, if limited numbers of trees appear infected then it may be prudent to fell and destroy infected individuals to reduce infection levels and reduce the risk of the disease spreading.

[26] https://www.aphis.usda.gov/plant_health/plant_pest_info/asian_lhb/downloads/response-guidelines.pdf

h oaks representing the greatest proportion of species in Cranbrook in the Eco study, the ential loss from acute oak decline is **16%** percent of the tree population. This equates to roughly **98** susceptible trees.

The cost to replace the affected trees is estimated to be around **£1.37 Million**[27].

[27] Forest Research, 2020

Tree Health and Condition

One of the key factors in assessing the vulnerability of the resilience of a tree to pest and disease is the overall condition of the tree population. Tree condition was measured as part of this survey. Figure 20 and 21 (below) show the overall health of the trees in Cranbrook.

70% of the trees assessed in Cranbrook were considered to be in either excellent, good or fair condition, exhibiting less than 20% dieback. The small amount (3%) of dead dying and diseased trees are highly valuable and important for biodiversity. For context, Trees in Towns II found that a large majority (70%) of all surveyed trees were in good condition and very few (3%) were poor, dying or dead[28].

Two of the most common species of trees across Cranbrook were considered to be in excellent or good condition. These are **Ash** (*Fraxinus excelsior*) at 29.8% of the tree population and **English oak** (*Quercus robur*) at 11%.

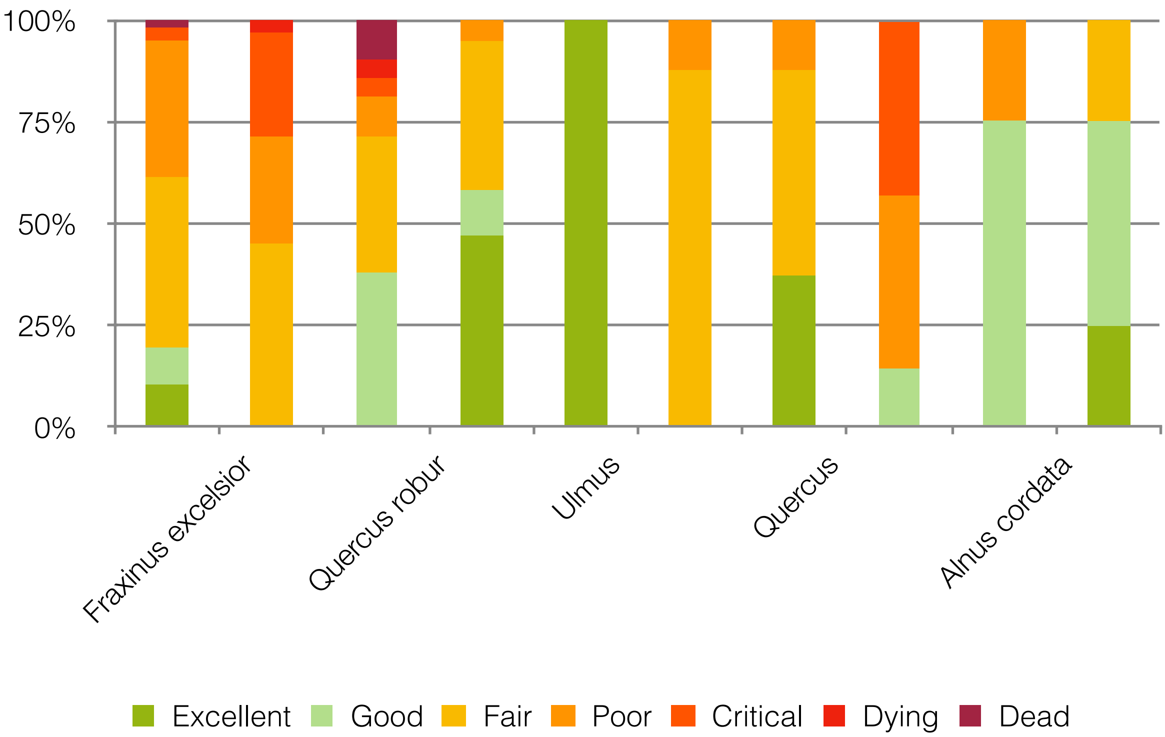


Figure 20: Overall Tree Health across Cranbrook for the 10 most common species

[28] Britt and Johnstone 2008

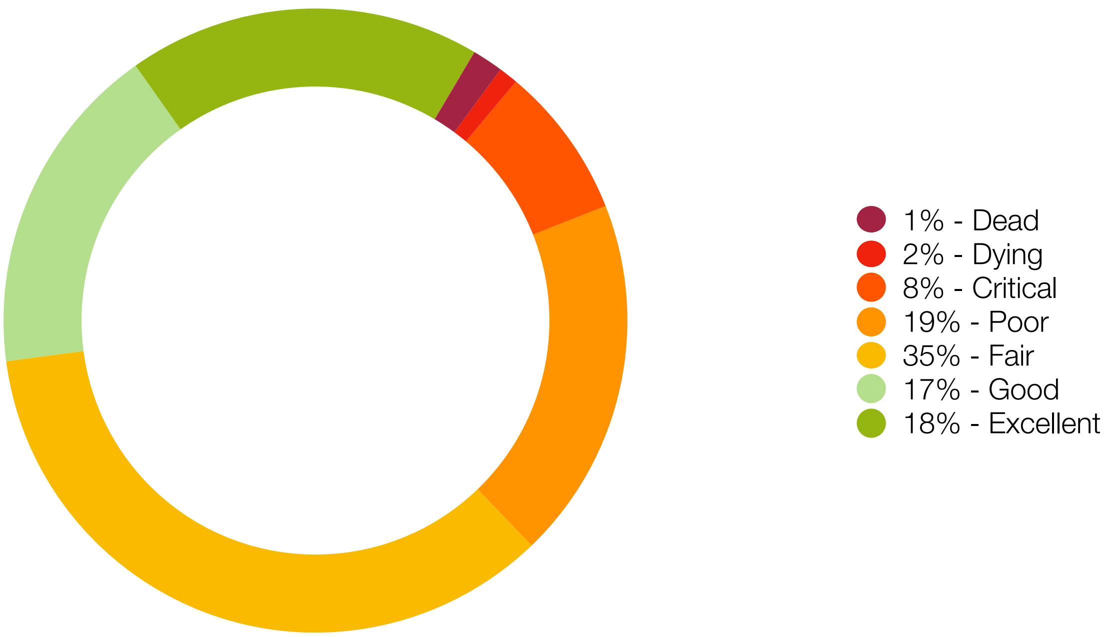


Figure 21: Overall tree condition Cranbrook (all species).

Pests, Disease and Tree Health

Recommendations

A whole host of pest and disease impacts could threaten the delivery of urban tree benefits across Cranbrook. Ash Dieback in particular poses a significant threat to Cranbrook's trees, and although ALB is not currently present in the UK it is still a potential threat.

The data collected as part of this study can provide an evidence base for funding and budgetary allocation, whilst also informing tree strategies and action plans that should seek to lessen the impact and improve the overall resilience of Cranbrook's urban forest in the short, medium and longer term.

Furthermore, overall tree health needs to be maintained and/or improved in order to increase resilience. Species selection for new tree planting should be informed by the latest research into novel pests and diseases.

It is therefore recommended that:

10. If not already in existence, a Pest Outbreak Action Plan is included as part of the overall tree strategy or urban forest management plan;

11. Future tree planting programs take account of and factor in tree diversity and pest and disease impacts, this is explored in more detail within the Tree Diversity section of this report;

12. To help deliver the overarching aims, tree health has to be addressed; strategies include:

i) Increasing area level species diversity, particular focussing on key species such as Ash (*Fraxinus excelsior)* which currently represent large proportions of the population and are at risk from pests and diseases;

ii) Maintaining good health and condition through regular pruning and inspections.

iii) Implement and maintain biosecurity procedures and practices to minimise risk of outbreak.

Policy Context

With our changing climate, urban planning must strive to implement sustainable practices and prioritise urban forests, as explored within the UNFAO urban and peri-urban forestry guidelines. Environmental Contributions and improvements to health and wellbeing are important considerations[29]. The Kyoto Protocol focused on the need to reduce greenhouse gas emissions through targets relating to the following pollutants; CO_2 (Carbon Dioxide), CH_4 (Methane), N_2O (Nitrous Oxide), HFC's (Hydrofluorocarbons), PFC's (perfluororcarbons) and SF_6 (Sulphur Hexafluoride)[30]. Cranbrook's trees remove 949 kg of atmospheric pollution annually, valued at £6,441. The carbon sequestration is equivalent to the carbon dioxide emissions from 37 family cars!

The UK Government's agenda is laid out in their 25 Year Environment Plan (25YEP). Amongst the targets, those that relate most to trees include: clean air; thriving plants and wildlife; sustainable and efficient use of resources; enhancing the beauty, heritage and engagement with the natural environment; mitigating and adapting to climate change; and enhancing biosecurity. Part of this is the recognised need to preserve our natural capital 'for future generations and for all the other creatures who share the globe with us'. Natural capital, ecosystem services and biodiversity net gain are considerations with increasing importance within the planning process are growing in importance. Street trees and urban woodlands are an important part of our urban green space, as defined in the Government's 25YEP: "The term 'green space' includes a range of environments also known as 'green infrastructure', including parks, playing fields, woodland, street trees, rights of way, allotments, canal towpaths, green walls and roofs.' (Page 16) 'Our aim is to improve existing green infrastructure by encouraging more investment while making sure there is a presumption for sustainable development.' (Page 77)

Targets within the Sustainable Development Goals (SDG's) Framework, developed by the UN, are directed towards cities. Of the 15 development goals, urban forests can contribute towards meeting 9 of these, as illustrated in Table 3 (overleaf).

"Although cities occupy only 2 percent of the planet's surface, their inhabitants use 75 percent of its natural resources"
- FAO, 2016

29 UNFAO (2016)

30UNFCCC (2008)

The EU Forest Strategy 2014-2020 provides a framework for National Policy within the UK. As with the above polices, the need to prioritise urban forests alongside our changing environment is stressed within the opening sentences, ‘Forests and other wooded land cover over 40% of the EU’s land area, with a great diversity of character across regions. Afforestation and natural succession have increased the EU’s forest area by around 0.4% per year over recent decades. Globally, however, forest area continues to decrease’. The policy also highlights the importance of urban forests with regards to habitats, mitigation of climate change and the provision of ecosystem services[31].

The EU Forest Strategy promotes taking a more balanced view of managing urban forests and takes into consideration the range of services trees contribute to our communities.

The EU Policy’s objectives for 2020 are as follows:

To ensure and demonstrate that all forests in the EU are managed according to sustainable forest management principles and that the EU’s contribution to promoting sustainable forest management and reducing deforestation at global level is strengthened, thus:

- contributing to balancing various forest functions, meeting demands, and delivering vital ecosystem services.

- providing a basis for forestry and the whole forest-based value chain to be competitive and viable contributors to the bio-based economy.

Sustainable Development Goals	The Role of Urban Forests
1 NO POVERTY	Trees in cities provide valuable ecosystem services, improve the aesthetic appearance, create opportunities for employment, increase economic activity through their presence by positively affecting consumer footfall and expenditure, alongside raising the value of properties within the community.
2 ZERO HUNGER	Urban Forests can contribute towards this development goal through the provision of natural products such as, fruit, seeds and fungi and other associated species. Additionally they support healthy lifestyles indirectly through "*affordable woodfuel*", clean water and higher quality soils.
3 GOOD HEALTH AND WELL-BEING	Urban Forests encourage healthy lifestyles and can lead to increased levels of wellbeing and mental health. Open spaces can be used for exercise and recreational activities. Air quality can be directly improved through the removal of pollutants by trees.
6 CLEAN WATER AND SANITATION	According to the UN FAO guidance Urban Forests are "*efficient regulators of urban hydrological cycles. They filter drinking water by reducing biological and chemical pollutants, reduce the risk of floods and erosion, and reduce water losses by minimizing mesoclimatic extremes through evapotranspiration processes*"
7 AFFORDABLE AND CLEAN ENERGY	Renewable energy such as wood fuel, can be produced by urban forests. In some parts of the world wood fuel energy is "*the most affordable and sometimes only available source*"
8 DECENT WORK AND ECONOMIC GROWTH	Trees in cities provide improved aesthetics for business and tourism which leads to a greater property value, increased rental fees, job opportunities and cost savings (in terms of energy and healthcare).
11 SUSTAINABLE CITIES AND COMMUNITIES	Urban forests protect cities through reducing storm water runoff, they mitigate climate change and in addition to environmental ecosystem services, they can contribute towards improvements in nutrition, exercise and mental health and spaces for social cohesion.
13 CLIMATE ACTION	Through carbon storage and sequestration urban forests directly reduce greenhouse gas emission. As discussed earlier, as a result of their physical presence trees can enable urban cooling and mitigate flooding through reductions in storm water runoff. They also produce oxygen, filter pollution and reduce energy costs.
15 LIFE ON LAND	Trees improve soil quality and enhance local biodiversity. Many small mammals, birds and invertebrates rely on the habitats trees provide.

Table 3: The role of trees in relation to the Sustainable Development Goals devised by the United Nations Food and Agriculture Organisation[1].

National Policy

The Government's Forestry and Woodland Policy Statement recognises the key role of the urban forest in engaging people with trees and woodlands on their doorstep. It notes the importance of valuing our urban trees, using tools such as i-Tree[32].

Urban forests can also contribute to meeting objectives 1 and 4 of Defra's 2020 strategy. These involve a cleaner, healthier environment (1) and a nation protected against floods and other hazards (4)[33].

The revised National Planning Policy Framework (NPPF - July 2018) makes specific mention of trees and woodland more frequently than the document which preceded it, where protection of 'aged or veteran trees' was strengthened and prioritised. Trees and urban tree cover are implicitly linked to other key concepts which are emphasised and highlighted within the framework.

Sustainability, ecosystem services and green infrastructure are all dependent on the significant contribution that trees in the urban forest make.

Of the 16 sections in the revised NPPF, trees are able to contribute to meeting the objectives of 11 of them.

Trees, and the benefits which they provide are crucial to securing economic, social and environmentally sustainable development (NPPF Section 2, "*Achieving sustainable development*"). Trees contribute to positive improvements in the quality of the built and natural environment and also have a central role to play in the strategic policy making of local authorities.

Paragraph 20 of the NPPF sets out how council policies must make provisions for the:

"*conservation and enhancement of the natural, built and historic environment, including landscapes and green infrastructure, and planning measures to address climate change mitigation and adaptation*"[34].

[32] Defra (2013)

[33] Defra (2016)

[34] Ministry of Housing, Communication and Local Government (2018)

Increased tree cover can increase economic growth[35] and prosperity[36] as leafier environments improve consumer spending. Additionally, businesses are prepared to pay greater ground rents[37], also associated with higher paid earners who are more productive[38], house prices increase and crime is reduced[39]. This accords with NPPF (Section 6) "*Building a strong, competitive economy*" and is also directly linked to (Section 7) "*Ensuring the vitality of town centres*". Furthermore, trees also contribute to "*Supporting a prosperous rural economy*" (included as a separate heading within Section 6 "*Building a strong, competitive economy*"), through the provision of non woody forest products, wood fuel and timber.

Trees also improve journey quality[40] (Section 9) "*Promoting sustainable transport*" and can encourage use of alternative transport corridors such as pavements and cycleways[41]. Additionally, trees near road networks absorb pollution and airborne particulates, helping to fulfil obligations under local air quality action plans[42], reduce noise[43] and lower traffic speeds[44].

The presence of trees helps to improve property prices thereby contributing to delivering a wide choice of high quality homes, a theme which is central to the NPPF. The incorporation of trees into new development, when done in the right way so that there is minimal conflict, will provide a positive contribution to good design. Section 12 of the NPPF "*Achieving well-designed places*" refers in many place to principles which would benefit from the careful consideration of the use of trees in development design.

Trees not only contribute to 'attractive' and 'comfortable' streetscapes (or treescapes) but are are an asset, which delivers even greater benefits as they grow, adding to the quality of the area during, over and above the lifetime of the development (paragraph 127). They are essential to the incorporation of 'green and other public space' (paragraph 127e) and in the 'provision of safe and accessible green infrastructure' (paragraph 91). Local authorities must also 'plan positively for the provision and use of shared spaces, community facilities...' (paragraph 92), which includes the provision of public open space. Increases in tree cover have even been shown to reduce crime therefore helping to

"Trees are key to enhancing biodiversity and providing places of recreation"

35 Rolls and Sunderland (2014)

36 Wolf (2005

37 Laverne &. Winson_Geideman, 2003

38 Kaplan, 1993; Wolf, 1998

39 Wolf (2007), Kuo & Sullivan (2001a, 2001b)

40 Davies et al., 2014

41 Trees and Design Action Group, 2014

42 Escobedo and Nowak, 2009

43 Van Renterghem, 2014; Van Renterghem et al., 2012

44 Mok et al., 2003

ensure places are 'safe and accessible' (paragraph 91).

Trees help in delivering the requirements of Section 8 "*Promoting healthy and safe communities*". There is a growing body of research that shows people are happier in leafier environments and with access to the natural environment: hospital recovery times[45] and stress[46] are reduced and birth weights are increased[47], meaning fewer health issues later in life. Conversely, when tree cover is reduced, asthma rates and respiratory problems often increase. Trees thereby promote healthy communities. They also provide a cultural link to the wider environment (paragraph 172) and act as a focal point for shared space and can improve the provision of high quality open space (paragraph 96).

In "*Protecting Greenbelt*" (Section 13) trees are also key to enhancing biodiversity and providing places of recreation (paragraph 141). Trees are also fundamental to strategies which aim to help "*Meet the challenge of climate change, flooding and coastal change*" (Section 14). Trees reduce stormwater runoff by attenuating precipitation in their canopies[48] and also reduce peak summer temperatures. temperatures in both the urban and wider environment by several degrees[49], thereby helping to:

'...*shape places in ways that contribute to radical reductions in greenhouse gas emissions, minimise vulnerability and improve resilience; encourage the reuse of existing resources, including the conversion of existing buildings; and support renewable and low carbon energy and associated infrastructure*' (paragraph 148).

Additionally, "*Plans should take a proactive approach to mitigating and adapting to climate change, taking into account the long-term implications for flood risk, coastal change, water supply, biodiversity and landscapes, and the risk of overheating from rising temperatures[48]. Policies should support appropriate measures to ensure the future resilience of communities and infrastructure to climate change impacts*" (Paragraph 149).

New development should be planned to avoid increased vulnerability to the range of impacts arising from climate change. When new development is brought forward in areas which are vulnerable, care should be taken to ensure that risks can be managed through suitable adaptation measures,

45 Ulrich, 1984

46 Korpela et al., 2008; Hauru et al., 2012

47 Donovan et al., 2011

48 Thomas and Nisbet, 2007; Nisbet and Thomas, 2006

49 Doick and Hutchings, 2012

uding through the planning of green infrastructure (GI) - this means trees are often the single gest component of GI.

Perhaps most commonly understood is trees' ability to "***Conserve and enhance the natural environment***" (Section 15). Specifically, in Paragraph 170 of the NPPF it states that:

"*Planning policies and decisions should contribute to and enhance the natural and local environment…*" "*…recognising the intrinsic character and beauty of the countryside, and the wider benefits from natural capital and ecosystem services – including the economic and other benefits of the best and most versatile agricultural land, and of trees and woodland*" (Paragraph 170 b).

A key reason for using tree canopy cover as a tool to maintain and enhance tree cover across the country and within individual developments is that it offers a means by which improvements and "*development whose primary objective is to conserve or enhance biodiversity should be supported; while opportunities to incorporate biodiversity improvements in and around developments should be encouraged, especially where this can secure measurable net gains for biodiversity (Paragraph 175)*". Measuring canopy cover provides a means by which net change in habitat and biodiversity can be monitored.

As well as providing economic benefit, previously planted trees provide a cultural link to the past, "***Conserving and enhancing the historic environment***" (Section 16) and protecting and enhancing valued landscapes. Old mature and veteran trees that have cultural significance will require more than just the consideration of their habitat and biodiversity and amenity value.

The Government attaches great importance to the design of the built environment. Trees make a significant contribution to good design and good design is a key aspect of sustainable development, is indivisible from good planning, and should contribute positively to making places better for people.

Regardless of any other 'external drivers', under the current legislation[50], LPAs have a statutory duty to consider the protection and planting of trees when granting planning permission for proposed development. The potential effect of development on trees, whether statutorily protected (e.g. by a tree preservation order or by their inclusion within a conservation area) or not, is a material consideration that must be taken into account when considering planning applications. In order to exercise that duty adequately, LPAs need to have an understanding of the existing tree resource so that they can make an informed judgement about what might be needed/appropriate, in terms of tree impact, from developments.

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50 TCPA Act 1990

The UK Government has a 2018 ‘Tree Health Resilience Strategy’[51] with the aim to protect trees from pests and disease. They emphasise 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; encouragement of healthy tree condition. (Page 7). In support of the 25YEP, in November 2019 the UK Government launched at £50 million tree-planting scheme, known as the Woodland Carbon Guarantee. This provides land managers with financial incentives to sequester carbon as trees grow.

51 Tree Health Resilience Strategy, 2018

Turning Data into Action

Using the data from this study, the information in this report, and other ongoing work, Cranbrook Council drafted 5 key aims, each of which can be addressed by the recommendations previously outlined in this report. These are presented in Table 4 (below).

Overall this report and its associated data can provide a baseline on the urban forest structure and its benefits. In doing so, this can support decision makers within the council to achieve social and economic and environmental objectives.

In order to meet the recommendations previously outlined in this report and address the aims supplied by Cranbrook Town Council, an overarching strategic urban forest master plan is recommended. It should contain a minimum 20-year vision and be reviewed and updated every 5-7 years[52].

<table>
<tr><th>Key Aims</th><th>Measurable</th><th>Action</th></tr>
<tr><td>Increase Tree Canopy Cover</td><td>% canopy cover.</td><td rowspan="6">Complete a business case for an urban forest master plan to ensure the actions are properly implemented and audited.</td></tr>
<tr><td>Increase resilience of the tree population to pest, disease and climate change</td><td>% of disease resilience (species susceptible and immune).</td></tr>
<tr><td>Identify and investigate areas of potential plantable space, particularly in areas of high social need</td><td>% of plantable space which is planted</td></tr>
<tr><td>Optimise street tree planting for air pollution removal</td><td>Carry out a multiple criteria analysis using GIS to identify potential planting sites for further investigation</td></tr>
<tr><td>Raise awareness of the importance of Cranbrook's urban forest to increase public engagement and understanding</td><td>No of stakeholders and public involved in urban forest activities</td></tr>
<tr><td>Prevention of Insurance claims for subsidence</td><td>No of claims</td></tr>
</table>

Table 4: Key Aims for Cranbrook Council

52 For a good example of such see The Mersey Forest Plan: https://www.merseyforest.org.uk/about/plan/

Cranbrook's Canopy Cover Target

Cranbrook is looking to work towards increasing canopy cover in the next 20 to 50 years. The existing canopy cover of Cranbrook is 14.3%.

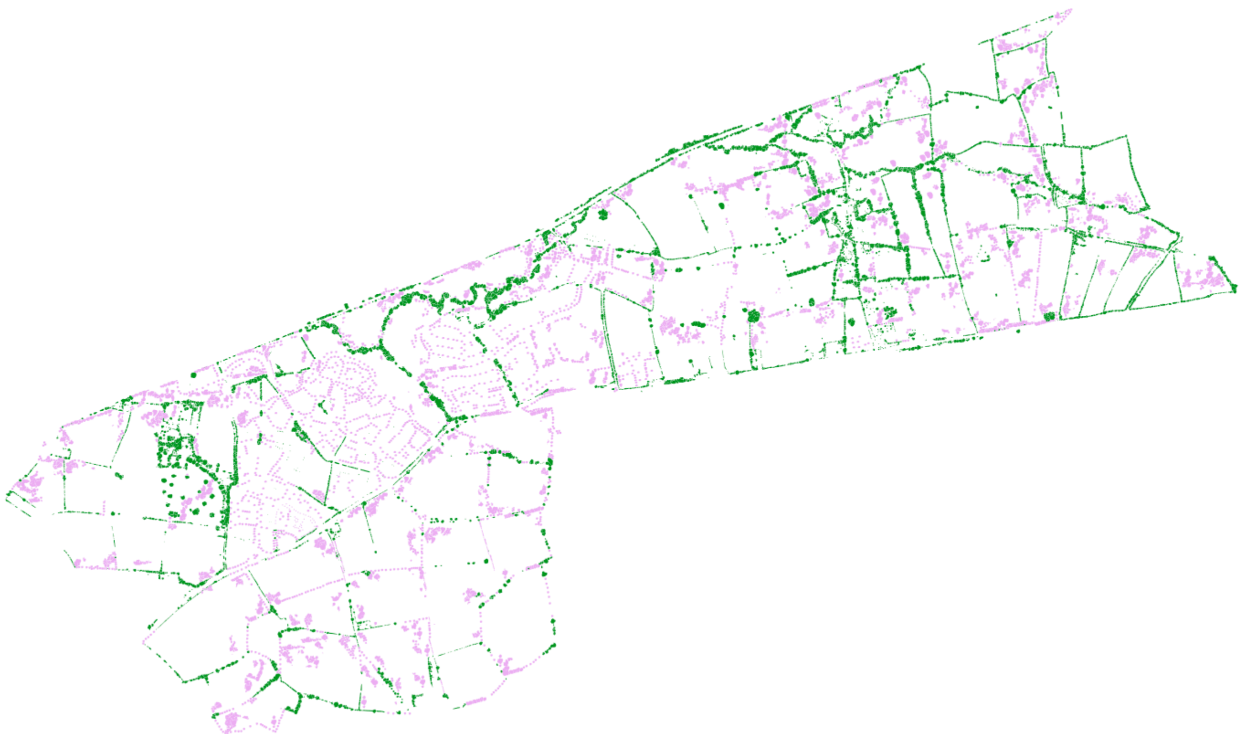
Figures 22 and 23 are interpretations of what a 30% target could look like for Cranbrook. They have been created using a Geographical Information System (GIS). Polygons to represent trees were placed in 'potentially plantable areas' (where there is no existing vegetation or hard infrastructure), until 30% of the area is covered by trees.

Figure 22 (below) shows what this 30% canopy cover could look like.

Figure 23 (overleaf) breaks this 30% coverage down into the existing canopy cover (14.3%) in green, and the additional trees that would need to planted to make up this total in pink.

Figure 22: An interpretation of what 30% canopy cover in Cranbrook could look like.

Figure 23: Existing canopy cover (green) and additional trees needed (pink) to make up 30% canopy cover.



Replacement Cost

In addition to estimating the environmental benefits provided by trees the i-Tree Eco model also provides a structural valuation of the trees in the urban forest. In the UK this is termed the 'Replacement Cost'. This value is the cost of replacing one tree with another similar specimen and is derived using the Council of Tree and Landscape Appraisers (CTLA) methodology[53]. The formula allows for tree suitability in the landscape and nursery prices.

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.

Replacement Cost is intended to provide a useful management tool, as it is able to value what it might cost to replace any or all of the trees (taking account of species suitability, depreciation and other economic considerations) should they become damaged or diseased for instance. The replacement costs for the ten most valuable tree species are shown in Figure 24 (below).

The total replacement cost of all trees in Cranbrook currently stands at **£4.8 million.**

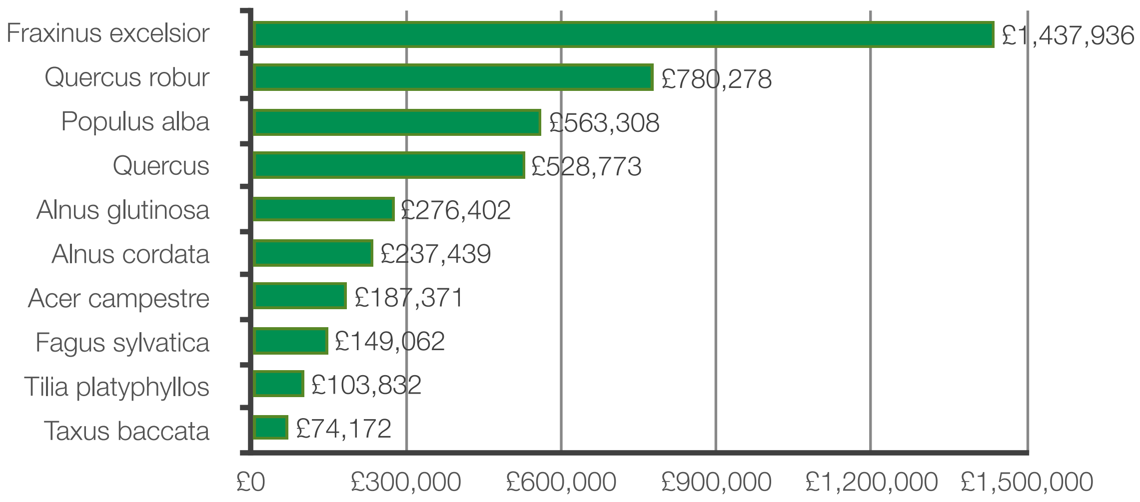


Figure 24: Replacement cost of the ten most valuable trees in Cranbrook (i-Tree Eco sample survey).

Ash (*Fraxinus* excelsior) is the most valuable species of tree, on account of both its size and population, followed by English oak (*Quercus robber*) and poplar (*Populus alba*). These three species of tree account for **£2,781,522** (58%) of the total replacement cost of the trees in Cranbrook. A full list of trees with the associated replacement cost for Cranbrook is given in Appendix III.

[53] Hollis (2007)

CAVAT - The amenity value of trees

Replacement cost is the cost of replacing the urban forest of Cranbrook should it be lost. The CTLA valuation method does not take into account the health or amenity value of trees, and is a management tool rather than a benefit valuation.

As such, a Capital Asset Value for Amenity Trees (CAVAT) valuation, which considers the health of trees and their public amenity value, was also undertaken. For the urban forest of Cranbrook, the estimated total public amenity asset value is **£57.8 million**. This equates to around £108,000 per hectare.

Further details on the CAVAT method are given in Appendix I.

Across the whole of Cranbrook, Ash (*Fraxinus* excelsior) had the highest overall value, representing 25.3% of the total public amenity value of all the trees in Cranbrook's urban forest. The single most valuable tree encountered in the study was an Oak (*Quercus*), estimated to have an asset value of £58,000. The top ten species based on their CAVAT values are given in Table 5 (below).

Species	CAVAT Value	Percent of Total Population	Replacement Cost
Fraxinus excelsior	£14,653,736	30%	£1,437,936
Quercus	£10,460,026	11%	£528,773
Quercus robur	£9,674,784	4%	£780,278
Acer campestre	£5,199,487	4%	£187,371
Populus alba	£4,001,787	16%	£563,308
Alnus glutinosa	£2,883,739	2%	£276,402
Fagus sylvatica	£1,903,892	10%	£149,062
Ulmus minor	£1,654,652	2%	£55,952
Alnus cordata	£1,293,366	1%	£237,439
Malus	£810,403	5%	£59,576
All Other Species	£5,354,750	15%	£547,624
Total	£57,890,620	100%	£4,823,722

Table 5: % of CAVAT values by species

The Cranbrook CAVAT figures can also be broken down using the land use data collected as part of the i-Tree Eco survey. This is useful to determine where there may be a lack of, or need for, enhancement of the tree population to improve amenity.

The land use type containing the highest CAVAT value of trees is 'Park', with over 60% of the total value of the trees and estimated value of approximately £543,518, highlighting their importance as public spaces and areas where trees can become large, accessible and appreciated in value. This equates to greater than £35 million when extrapolated for the whole of Cranbrook.

Appendix I

Notes on Methodology

i-Tree Eco is designed to use standardised field data from randomly located plots 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 and <10 microns).
- Total carbon stored and net carbon annually sequestered by trees.
- 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 (but not limited too) Asian longhorned beetle, Acute oak decline and Ash Dieback.

In the field, 0.04 hectare plots were randomly distributed. All field data were collected during the leaf-on season to properly assess tree canopies. Within each plot, data collection includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback.

To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations[54]. To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the

[54] Nowak, 1994

amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of trees account for decomposition[55].

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

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulphur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models[56]. 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[57] [58] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere[59].

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis. The value of avoided runoff is based on estimated or user-defined local values. As the local values include the cost of treating the water as part of a combined sewage system the lower, national average externality value for the United States is utilised and converted to local currency with user-defined exchange rates.

Replacement Costs were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition and location information[60,61].

55 Nowak, Hoehn and Crane, 2007

56 Baldocchi, Hicks and Camara, 1987 and Baldocchi, 1988

57 Bidwell and Fraser, 1972

58 Lovett, 1994

US externality and UK social damage costs

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

For the UK however, the appropriate way to monetise the carbon sequestration benefit is to multiply the tonnes of carbon stored by the non-traded price of carbon, because this carbon is not part of the EU carbon trading scheme. The non-traded price is not based on the cost to society of emitting the carbon, but is based on the cost of not emitting the tonne of carbon elsewhere in the UK in order to remain compliant with the Climate Change Act [62].

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

Official pollution values for the UK are based on the estimated social cost of the pollutant in terms of impact upon human health, damage to buildings and crops. Values were taken from the Interdepartmental Group on Costs and Benefits (IGCB) based on work by DEFRA[63]. They are a conservative estimate because they do not include damage to ecosystems; SO2 negatively impacts trees and freshwater and NOx contributes to acidification and eutrophication. For PM10s, which are the largest element of the air pollution benefit, a range of economic values is available depending on how urban (hence densely populated) the area under consideration is. We used the 'transport outer conurbation' values as a conservative best fit, given the population density data above.

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

For a full review of the model see UFORE (2010 and Nowak *et al.* (2010).

For UK implementation see Rogers *et al.* (2012).

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[62] DECC, 2011

[63] DEFRA, 2007

CAVAT

An amended CAVAT method was chosen to assess the trees in this study, in conjunction with the CAVAT steering group (as done with previous i-Tree Eco studies in the UK).

In calculating CAVAT the following data sets are required:

- the current Unit Value,
- Diameter at Breast Height (DBH),
- the CTI (Community Tree Index) rating, reflecting local population density,
- an assessment of accessibility,
- an assessment of overall functionality, (that is the health and completeness of the crown of the tree);
- an assessment of Safe Life Expectancy.

The current Unit Value is determined by the CAVAT steering group and is currently set at £15.88 (LTOA 2012).

DBH is taken directly from the field measurements.

The CTI rating is determined from the approved list (LTOA 2012) and is calculated on a borough by borough basis.

Accessibility, ie the ability of the public to benefit from the amenity value of tree, was generally judged to be 100% for trees in Parks, street trees and other open areas, and was generally reduced for residential areas and transportation networks to 60% (increased to 100% if the tree was on the street), to 80% on institutional land uses and to 40% on Agricultural plots. A full list is given in table X1 below.

On open spaces we divided the trees into those with 100% exposure to light, and the others, which occurred in groups. On the basis that trees in open spaces are less intensively managed we applied an 80% functionality factor to all the individual trees, a 60% factor for those in small groups and a 40% factor for those in large groups. One could simply apply an overall figure for these too, but it would not then reflect how significant a proportion of the population the trees in groups are.

Safe Life Expectancy assessment was intended to be as realistic as possible, but based on existing circumstances. For full details of the method refer to LTOA (2010).

CAVAT Assessment

Functionality was calculated directly from the amount of canopy missing.

The particular nature of local street trees, local factors and choices could not be taken into account as part of this study. The value should reflect the reality that street trees have to be managed for safety. They are frequently crown lifted and reduced (to a greater or lesser extent) and are generally growing in conditions of greater stress than their open grown counterparts. As a result they may have a significantly reduced functionality under the CAVAT system.

Land Use	Street Tree	Accessibility %
Agriculture	S	100
Agriculture	N	40
Cemetery	S	100
Cemetery	N	80
Comm/Ind	S	100
Comm/Ind	N	40
Golf Course	S	100
Golf Course	N	60
Institutional	S	100
Institutional	N	80
Multi Family Residential	S	100
Multi Family Residential	N	80
Other	S	100
Other	N	60
Park	S	100
Park	N	100
Residential	S	100
Residential	N	60
Transportation	S	100
Transportation	N	40
Utility	S	100
Utility	N	20
Vacant	S	100
Vacant	N	80
Water/Wetland	S	100
Water/Wetland	N	60

Table 6: Accessibility Figures for CAVAT

Appendix II - Dominance Values - Sample survey

Rank	Scientific Name	% Population	% Leaf Area	DV
1	Fraxinus excelsior	29.80	28.10	57.90
2	Acer campestre	16.20	10.70	26.90
3	Quercus robur	11.00	14.70	25.70
4	Ulmus minor	9.90	4.00	13.90
5	Quercus	4.20	6.50	10.60
6	Populus alba	4.20	6.40	10.60
7	Ulmus	4.70	3.50	8.20
8	Alnus cordata	2.10	5.40	7.50
9	Tilia platyphyllos	1.60	3.70	5.30
10	Fagus sylvatica	1.00	4.20	5.20
11	Alnus glutinosa	2.10	3.00	5.10
12	Crataegus monogyna	3.70	1.10	4.80
13	Taxus baccata	1.00	2.10	3.20
14	Salix	0.50	1.90	2.50
15	Salix caprea	1.60	0.80	2.40
16	Malus	0.50	1.40	1.90
17	Quercus cerris	0.50	1.20	1.70
18	Acer pseudoplatanus	1.00	0.30	1.40
19	Juglans nigra	0.50	0.50	1.00
20	Cupressocyparis leylandii	0.50	0.30	0.80
21	Pyrus communis	0.50	0.10	0.70
22	Pyrus calleryana	0.50	0.10	0.60
23	Pinus sylvestris	0.50	0.10	0.60
24	Alnus	0.50	<0.10	0.60
25	Morus alba	0.50	<0.10	0.60
26	Prunus avium	0.50	<0.10	0.60

Appendix III - Species List - Sample survey

Species	Number of trees	Carbon stored (mt)	Gross Seq (mt/yr)	Leaf Area (ha)	Leaf Biomass (mt)	Replacement Cost (£)
Acer campestre	1,135	137.07	4.85	9.47	5.33	£ 187,371.08
Acer pseudoplatanus	73	20.11	0.63	0.28	0.20	£ 35,513.52
Alnus	37	0.14	0.06	0.04	0.02	£ 3,328.38
Alnus cordata	146	113.40	3.86	4.78	3.48	£ 237,439.30
Alnus glutinosa	146	80.93	3.16	2.63	1.91	£ 276,402.42
Crataegus monogyna	256	21.81	0.87	0.97	1.21	£ 37,340.05
Cupressocyparis leylandii	37	8.70	0.28	0.24	0.37	£ 38,146.48
Fagus sylvatica	73	59.06	1.79	3.68	1.84	£ 149,061.78
Fraxinus excelsior	2,086	490.61	15.94	24.84	26.43	£ 1,437,936.20
Juglans nigra	37	5.24	0.27	0.41	0.33	£ 13,005.87
Malus	37	13.94	0.90	1.20	1.03	£ 59,575.98
Morus alba	37	0.27	0.09	0.04	0.03	£ 2,227.52
Pinus sylvestris	37	9.63	0.24	0.07	0.07	£ 30,582.33
Populus alba	293	282.61	5.20	5.67	4.93	£ 563,307.82
Prunus avium	37	0.23	0.09	0.04	0.03	£ 2,745.06
Pyrus calleryana	37	0.48	0.12	0.08	0.06	£ 2,525.45
Pyrus communis	37	0.73	0.17	0.12	0.09	£ 2,745.06
Quercus	293	212.60	6.93	5.71	5.64	£ 528,772.74
Quercus cerris	37	18.78	1.07	1.07	1.06	£ 63,305.69
Quercus robur	769	541.69	11.49	12.99	8.65	£ 780,278.14
Salix	37	12.44	0.37	1.71	1.06	£ 37,280.13
Salix caprea	110	14.25	0.81	0.70	0.45	£ 29,513.94

Species	Number of trees	Carbon stored (mt)	Gross Seq (mt/yr)	Leaf Area (ha)	Leaf Biomass (mt)	Replacement Cost (£)
Taxus baccata	73	11.35	0.52	1.89	2.95	£ 74,171.72
Tilia platyphyllos	110	31.82	1.08	3.27	1.94	£ 103,832.09
Ulmus	329	35.66	1.76	3.10	2.11	£ 71,361.54
Ulmus minor	695	41.74	3.36	3.51	2.39	£ 55,952.33
TOTAL	6,991	2165.30	65.90	88.50	73.61	£ 4,823,722.60

Appendix IV - Relative Tree Effects

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

Carbon storage is equivalent to:

- Amount of carbon emitted by 1,690 cars

- Amount of carbon emitted from 692 family homes

Nitrogen dioxide removal is equivalent to:

- Amount of carbon emitted by 17 cars

- Amount of carbon emitted from 8 family homes

Sulphur dioxide removal is equivalent to:

- Amount of carbon emitted by 629 cars

- Amount of carbon emitted from 2 family homes

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted by 100 cars

Oxygen production is equivalent to:

- The Oxygen consumed by 394 people per year

Average passenger automobile emissions per mile were based on dividing total 2002 pollutant emissions from light-duty gas vehicles (National Emission Trends http://www.epa.gov/ttn/chief/trends/index.html) divided by total miles driven in 2002 by passenger cars (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Average annual passenger automobile emissions per vehicle were based on dividing total 2002 pollutant emissions from light-duty gas vehicles by total number of passenger cars in 2002 (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Carbon dioxide emissions from automobile assumed six pounds of carbon per gallon of gasoline if energy costs of refinement and transportation are included (Graham, R.L., Wright, L.L., and Turhollow, A.F. 1992. The potential for short-rotation woody crops to reduce U.S. CO_2 Emissions. Climatic Change 22:223-238).

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