CAMBRIDGE CITY COUNCIL

Cambridge Canopy Project

An urban forestry initiative

Green Infrastructure Investment Pilot Briefing note

This plan sets out details of Cambridge City Council's green infrastructure investment pilot that forms part of the NSCiti2S project undertaken under the Interreg 2 Seas programme

Summary

Cambridge Canopy Project is Cambridge City Council's investment pilot for its larger parent project – Nature Smart Cities across the 2 Seas. The investment aims to help the City adapt to climate change by increasing tree canopy cover and contributing to the sustainable management of the City's urban forest.

It will complement and enhance the City's current arboricultural activities by developing several standard urban forestry approaches to tree planting, tree protection and public engagement. In addition, urban tree canopy assessment and prioritisation tools will be developed to support sustainable management of the City's tree stock, and to help identify areas for priority interventions.

It will directly contribute to, and encourage tree planting in the short-term and ensure increased levels of tree protection in the City. This will deliver benefits to help mitigate against the predicted changes in climate brought about by global climatic warming in the long-term.

Finally, the investment aspires to demonstrate to a wide target audience the value of investing in the urban forest, and that by applying one or more urban forest approaches, maintained and enhanced flows of ecosystem services can be achieved.

Version	Prepared by	Approved by	Date
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PART 1

Introduction to the investment pilot

Cambridge City Council is partnering with 7 other cities, 1 regional association, and 3 academic institutions from the UK, France, the Netherlands, and Belgium to deliver a climate change adaptation project under the Interreg 2 Seas European Territorial Cooperation Programme. The project is called 'Nature Smart Cities across the 2 Seas' (NSCiti2s). Cambridge City Council will contribute to delivering the project's overall objective to enable local authorities to self-finance green infrastructure investments. Cambridge City Council will also contribute to the delivery of the 5 main project outputs. Details of the programme, project, and investment pilot can be found in the accompanying Council document 'Interreg 2 Seas – Programme Project & Investment Brief'.

This plan sets out details of Cambridge City Council's green infrastructure investment pilot commitment under Work Package 3 of the NSCiti2S project. The pilot is entitled the 'Cambridge Canopy Project'; it is an urban forest initiative.

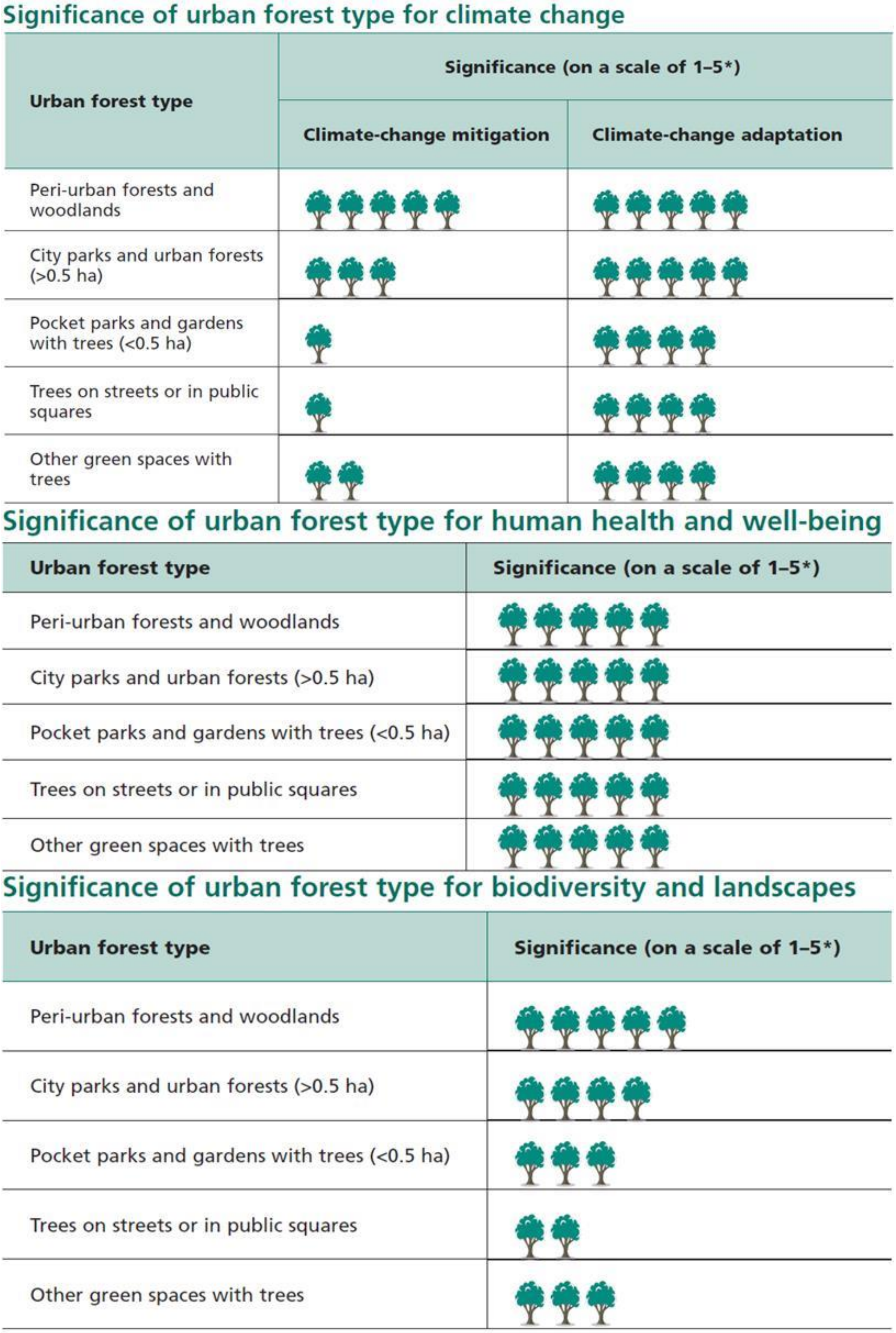
Background to the Cambridge Canopy Project

Green infrastructure and the urban forest

In urban areas, the elements of the natural environment which supply ecosystem services are referred to as 'green infrastructure'. Urban green infrastructure is not just made up of open spaces, such as parks, playing fields, cemeteries, allotments, and private gardens, but also constitutes green roofs and walls, trees, sustainable urban drainage systems (SUDs), as well as ponds and rivers. Human health and well-being can be considered the overarching outcome of optimal ecosystem service provision. Ecosystem services are the benefits that humans receive from ecosystems (Millennium Ecosystem Assessment, 2005); these flows of services range from food and water provision, to recreational opportunities, and climate regulation; collectively they support our well-being. Within urban areas the total stock of trees, regardless of ownership, forms a multifunctional network known as the urban forest; this network provides a key component of urban green infrastructure. Urban forests provide a range of benefits (see Figure 1, Figure 2 & Annex 1) and are the predominant provider of climate regulating ecosystem services in towns and cities. This is because, in comparison with other forms of green infrastructure in urban areas, trees are particularly effective at: alleviating summer heat through evaporation, transpiration, and shading; reducing storm water run-off by intercepting and absorbing water, and improving infiltration; and, enhancing air quality by intercepting and/or absorbing gaseous pollutants and particulate matter (Davies et al., 2017a).

In their own right, trees are not seen as being a specific land use, as is the case with many other types of green infrastructure. Trees can be fitted into many different land use types allowing a variety of activities to occur beneath their crowns. For example, highway trees overhang carriageways, and car parks can be covered by tree canopy.

Therefore, depending on how it is managed, the urban forest can be a particularly effective nature-based solution to climate change in urban centres, enabling adaptation to changing conditions through the ecosystem services they provide (Davies et al., 2017b; European Commission, 2015).



Significance of urban forest type for climate change

Urban forest type	Significance (on a scale of 1–5*)	
	Climate-change mitigation	Climate-change adaptation
Peri-urban forests and woodlands	5	5
City parks and urban forests (>0.5 ha)	3	5
Pocket parks and gardens with trees (<0.5 ha)	1	4
Trees on streets or in public squares	1	4
Other green spaces with trees	2	4

Significance of urban forest type for human health and well-being

Urban forest type	Significance (on a scale of 1–5*)
Peri-urban forests and woodlands	5
City parks and urban forests (>0.5 ha)	5
Pocket parks and gardens with trees (<0.5 ha)	5
Trees on streets or in public squares	5
Other green spaces with trees	5

Significance of urban forest type for biodiversity and landscapes

Urban forest type	Significance (on a scale of 1–5*)
Peri-urban forests and woodlands	5
City parks and urban forests (>0.5 ha)	4
Pocket parks and gardens with trees (<0.5 ha)	3
Trees on streets or in public squares	2
Other green spaces with trees	3

* Where 1 = very low significance and 5 = very high significance.

Figure 1 Significance of urban forest type for climate change, human health and well-being, and biodiversity and landscapes (taken directly from FAO, 2016)

Significance of urban forest type for economic benefits and green economy

Urban forest type	Significance (on a scale of 1–5*)
Peri-urban forests and woodlands	🌳🌳🌳🌳🌳
City parks and urban forests (>0.5 ha)	🌳🌳🌳🌳
Pocket parks and gardens with trees (<0.5 ha)	🌳🌳🌳
Trees on streets or in public squares	🌳🌳🌳
Other green spaces with trees	🌳

Significance of urban forest type for water and watersheds

Urban forest type	Significance (on a scale of 1–5*)	
	Watershed protection	Resilience to flooding events
Peri-urban forests and woodlands	🌳🌳🌳🌳🌳	🌳🌳🌳
City parks and urban forests (>0.5 ha)	🌳🌳	🌳🌳🌳🌳🌳
Pocket parks and gardens with trees (<0.5 ha)	*Not applicable*	🌳🌳🌳
Trees on streets or in public squares	🌳	🌳🌳🌳
Other urban green spaces with trees	🌳🌳🌳🌳	🌳🌳🌳🌳

Significance of urban forest type for sociocultural values

Urban forest type	Significance			
	Recreation	Education	Social cohesion	Social security and equity
Peri-urban forests and woodlands	🌳🌳🌳🌳	🌳🌳🌳🌳🌳	🌳🌳	🌳
City parks and urban forests (>0.5 ha)	🌳🌳🌳🌳🌳	🌳🌳🌳🌳	🌳🌳🌳🌳🌳	🌳🌳🌳🌳
Pocket parks and gardens with trees (<0.5 ha)	🌳🌳🌳	🌳	🌳🌳🌳	🌳🌳🌳🌳
Trees on streets or in public squares	🌳	🌳	🌳	🌳🌳🌳🌳🌳
Other green spaces with trees	🌳🌳🌳	🌳🌳🌳	🌳🌳	🌳🌳🌳

* Where 1 = very low significance and 5 = very high significance.

Figure 2 Significance of urban forest type for economic benefits and green economy, water and watersheds, and sociocultural values (taken directly from FAO, 2016)

What is urban forestry?

Urban forestry is a strategic approach to urban tree management that shifts the municipal focus away from just street and park trees, to managing, or seeking to influence the management of, all trees in public or private ownership. It recognises that most of the land and tree canopy cover in urban areas is outside of public ownership and direct control. It also seeks to shift the focus away from traditional management that predominantly centred on visual amenity, toward a consideration of maximising the wider range of ecosystem services and benefits provided by trees.

A sustainable urban forest includes everything needed to assure that the entire forest system achieves and maintains a healthy overall extent and structure, and that it is sufficient enough to continue providing ecosystem services and the desired benefits over time (Leff, 2016). Additionally, unlike traditional grey infrastructure which begins to depreciate as soon as it is installed, trees increase in value and provide greater flows of benefits as time passes.

What is tree canopy cover?

Tree canopy cover is the metric used to indicate the benefits provided by the urban forest. It is measured as tree canopy cover percentage of the total area under review. It has the advantage of being relatively simple and inexpensive to assess using spatial analysis techniques.

Increases in tree canopy cover can most efficiently be realised by maximising tree protection and maintenance in combination with new plantings. If trees are managed such that their anticipated mature crown projections are realised, significant canopy cover increases can occur in conjunction with new planting (Grove et al; 2006). As trees and their canopies take time to grow, more than twenty years will generally be needed to achieve a measurable change in canopy cover.

Cambridge City Council's arboricultural service

Cambridge City Council has a team of four arborists who directly manage 30,000 trees on the City's publicly owned open spaces, and by agreement with the County Council, its street trees. The team of arborists provide advice to all other City Council departments within the Council which own trees with more restricted access arrangements (e.g. commercial and residential property). The team also administers the UKs statutory tree protection regulations under the Town & Country Planning Act (1990) regarding trees in conservation areas and those protected by Tree Preservation Orders[1]. It also advises on development control issues for the Greater Cambridge Shared Planning Service.

Cambridge City Council's Citywide Tree Strategy 2016-2026 sets the Council's overall strategic vision for tree management in Cambridge. One of its strategic goals is to increase tree canopy cover from 17% to 19% by the 2050's. Resources have been limited during a time of austerity leading to difficulties in achieving this target, whilst at the same time maintaining the Council's business-as-usual activities (Cambridge City Council, 2016a). Lack of resource has been recognised as a key factor in the extent to which local authorities in the UK are able to realise the benefits of the urban forest, along with a lack of urban forest management objectives, and a lack of understanding of ecosystem

[1] Tree Preservation Order (TPO): An order made by a local authority or other planning authority to protect a tree, group of trees, area of (scattered) trees or woodland under Part VIII of the Town and Country Planning Act 1990. An order is generally made on the grounds of amenity and expediency. Anyone proposing works to a TPO tree must seek prior consent from the authority.

service delivery concepts within the local government, who are the primary delivery agents of urban forests (Davies et al., 2017b).

Cambridge's urban forest

At 17.1% Cambridge's tree canopy cover compares favourably with other cities in the UK (Doick, 2017); as it does in comparison with other UK cities of similar size, population, and ratio of the built and natural environment (Annex 2). However, as with many other UK cities, tree canopy cover in Cambridge has not historically been strategically planned for. The amount of tree canopy cover in an urban area can depend on many different variables. For example, these could include climate, geology, population, the built form and its density, land use type, age of primary development, as well as other social and economic factors (Lowry, 2012). Whilst these factors remain largely unassessed in Cambridge, land use type, the age of primary development, and building densities are considered important drivers in the development of the urban forest to date, affecting both distribution of canopy and tree size across the City. At a ward level, canopy cover varies from 12% to 22%, with the high densities of tree canopy cover in the west (Figure 3). Older and larger trees are disproportionally represented in the west of the City (Figure 6). Building densities in the west are considerably lower, and the age of primary development generally older (Figure 4), allowing tree canopy time and space to develop. Much of the land here is institutional, largely being owned and actively managed by the University of Cambridge and its colleges. Residential land use dominates to the east of the City. Residential land use has the greatest representation in Cambridge, comprising 39%; as a result, it supports a significant amount of tree canopy cover (ADAS, 2013). The 'open space' land use category has the largest trees of any land use type (ADAS, 2013), and also provides the greatest opportunities for new planting (Collas et al., 2016).

The majority of the City's green belt[2] consists of arable fields, with resulting poor tree cover. Since 2011, substantial urban growth has occurred in parts of the green belt, with new neighbourhoods on the Southern Fringe (~4,000 new homes) and in the North West Quadrant (~ 3,000 new homes)[3]. Tree canopy cover will increase in these areas as the resulting landscape mature.

The majority (74.1%) of tree canopy cover across the City is in private ownership or outside of the Council's direct control (Table 1, Figure 9). This figure is lower than the proportion of the land area it occupies (77%) possibly indicating opportunities for canopy enhancement. Conversely, the proportion of tree canopy (16.3%) owned by the Council is greater in proportion to the land area it occupies (13.5%) possibly reflecting the high amount of formal open space that it owns, with enhanced capacity for accommodating trees.

What is the capacity for improving tree canopy cover?

There are many ways to set tree canopy cover targets in urban areas, for example by political will, educated guesses, or derived from empirical data (Grove, 2006). Analysis of data of Cambridge's urban forest, collected in 2013, suggested a 2% increase in tree canopy, from 17% to 19%, was an

[2] A statutory designation made for the purposes of: checking the unrestricted sprawl of large built-up areas; preventing neighbouring towns from merging into each other; assisting in safeguarding the countryside from encroachment; preserving the setting and special character of historic towns and assisting in urban regeneration by encouraging the recycling of derelict and other urban land. Specific Green Belt purposes have been set out for Cambridge.

[3] https://www.cambridge.gov.uk/urban-growth

achievable target by the 2050's (ADAS, 2013). It was derived using the tree canopy cover averages for nine different land use types found in the City and was based on the assumption that land use was a key factor for determining the capacity for tree canopy cover (Britt et al., 2008).

Canopy cover improvements can be brought about by a combination of planting and protection. The main opportunities for planting by ward are summarised in Annex 3; it was found that these are heavily weighted toward residential, institutional, and open space land use types. The opportunities identified for planting assume that the land identified is both available for planting, and more importantly, that it is suitable for new planting. In some wards the area of canopy cover may legitimately be lower than the average due to a conflicting land use – for example, airports, military land and landfill sites, or due to being otherwise unsuitable for planting.

Modelling suggested around 16,000 trees planted over 5 years would develop, over a 30-year period, enough canopy to cover 2% of Cambridge's land area, assuming 25% losses over the same period. To realise an overall increase in tree canopy cover, increased tree protection and management was advocated to both protect new canopy growth and decrease mortality of the existing tree canopy cover.

A 2% increase in the total tree canopy cover in the City would be equivalent to 80 hectares[4] of land under new canopy. Annually, the Council removes, on average, 221 trees and plants about 250. The Council is responsible for around 23% of the City's land area and manages an estimated 30,000 trees. These trees make up approximately 26% of the total tree canopy cover for the City (ADAS, 2013).

Figure 7 shows the distribution of tree cover protected by Tree Preservation Orders or located within conservation areas. Wards to the east of the City have a much lower proportion of protection than wards to the west. This possibly reflects the relative ages of the tree stock in these areas. Large species trees supply greater flows of ecosystem services than smaller trees (Hand et al., 2019); as such, there may be capacity to increase protection on these trees that have not yet reached maturity.

[4] Approximately the same area as 112 football pitches.

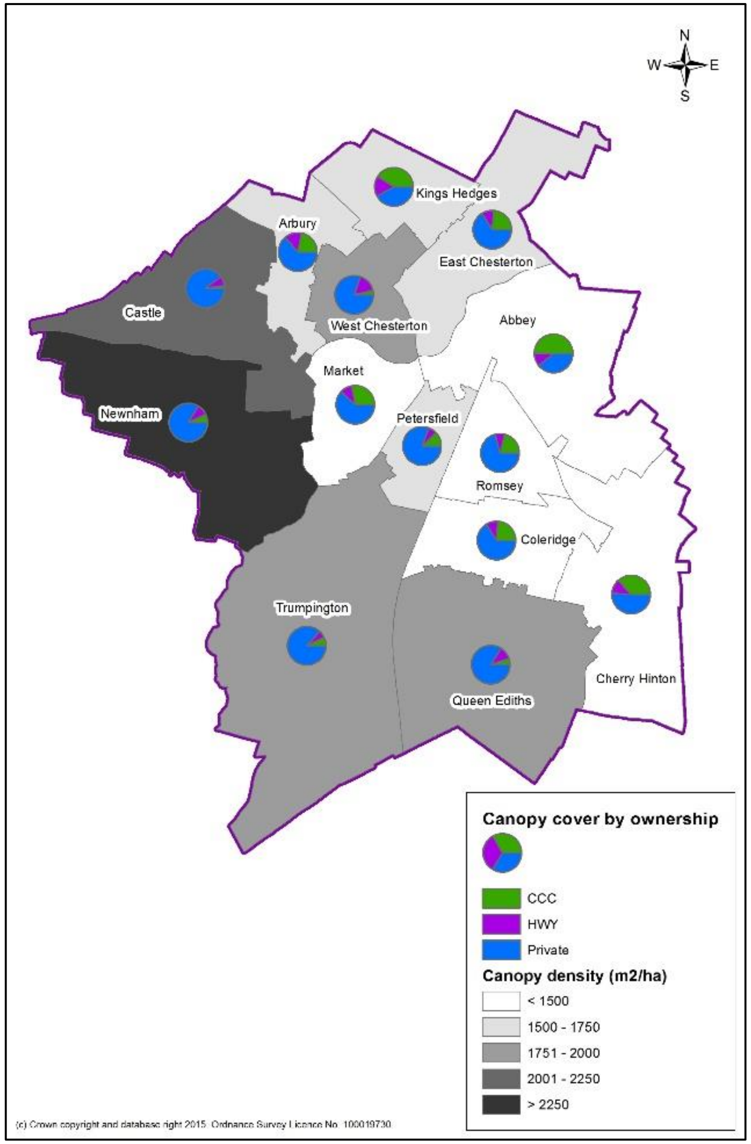


Figure 3 Tree canopy cover by ward and ownership

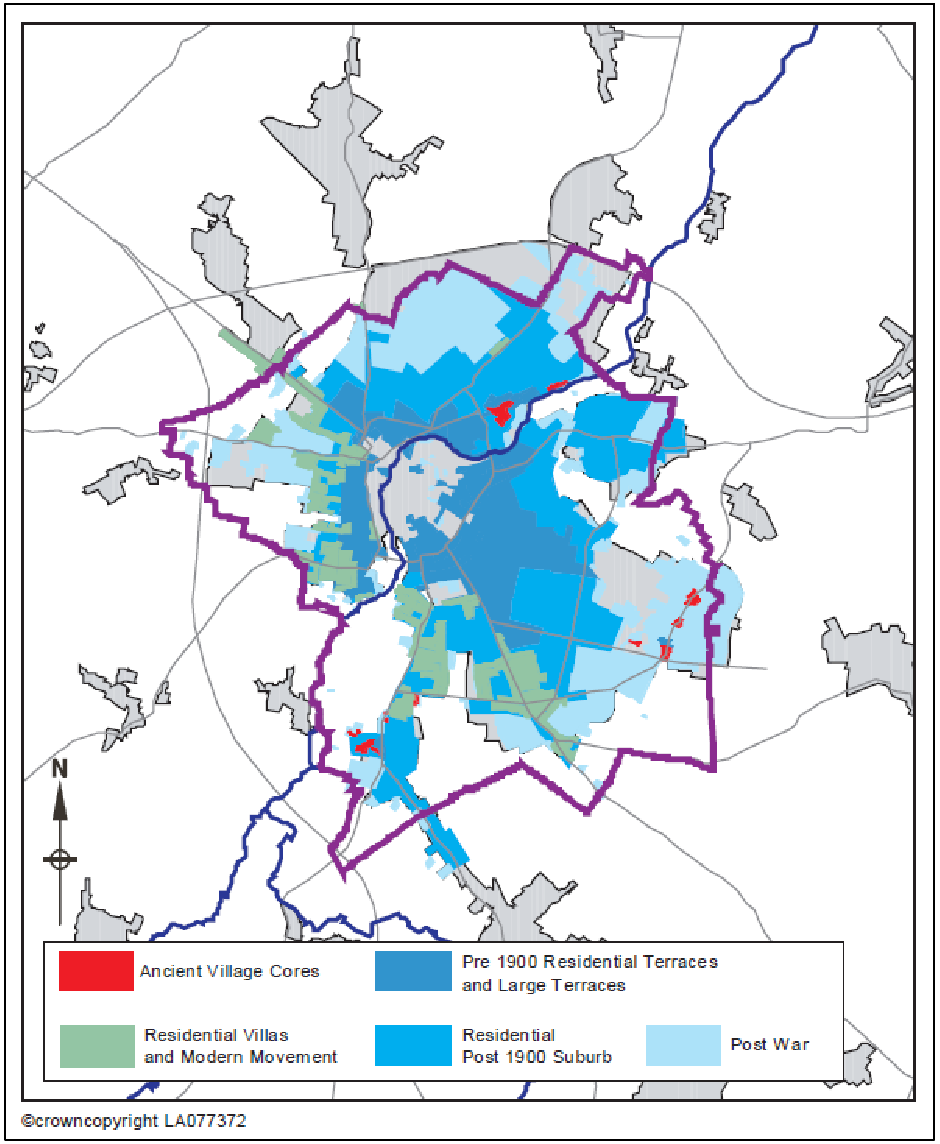


Figure 4 Primary age of development

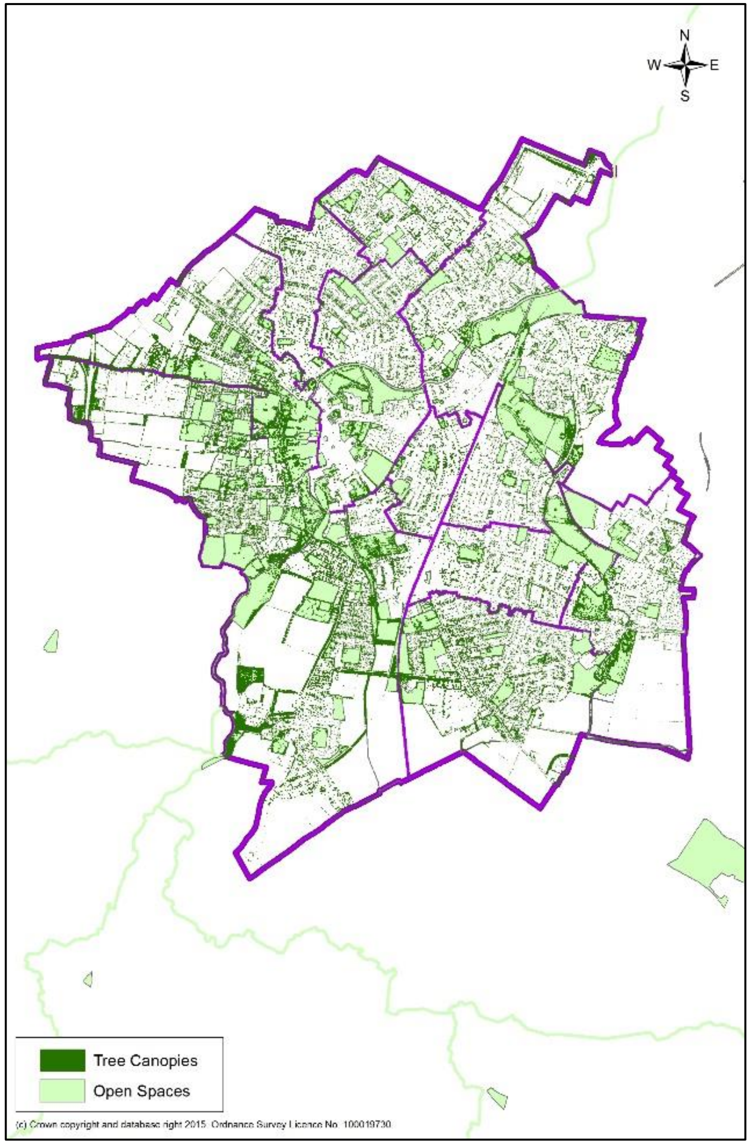


Figure 5 Tree canopy in relation to open space

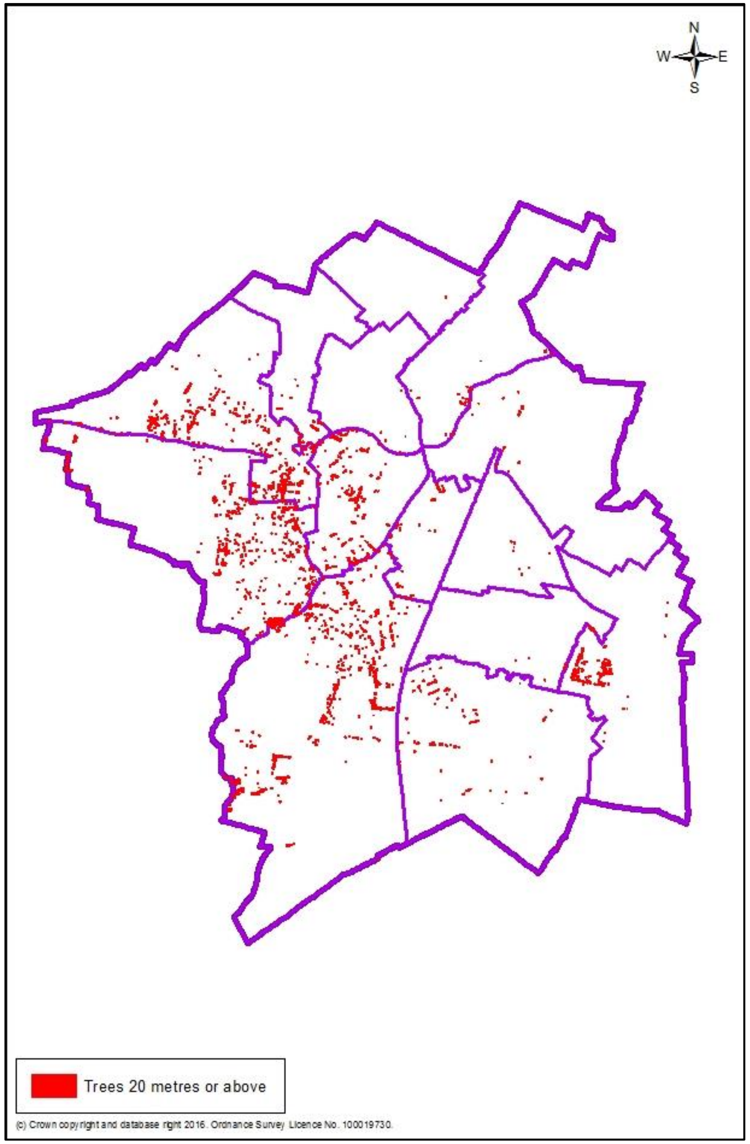


Figure 6 Distribution of trees over 20m

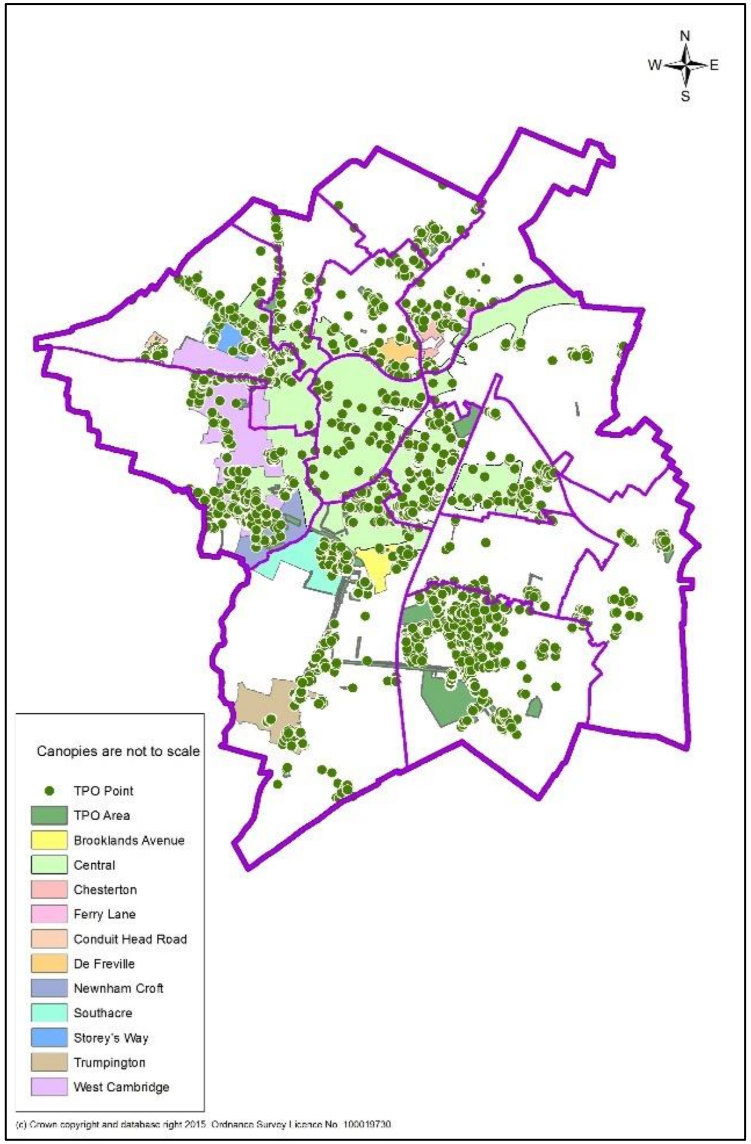
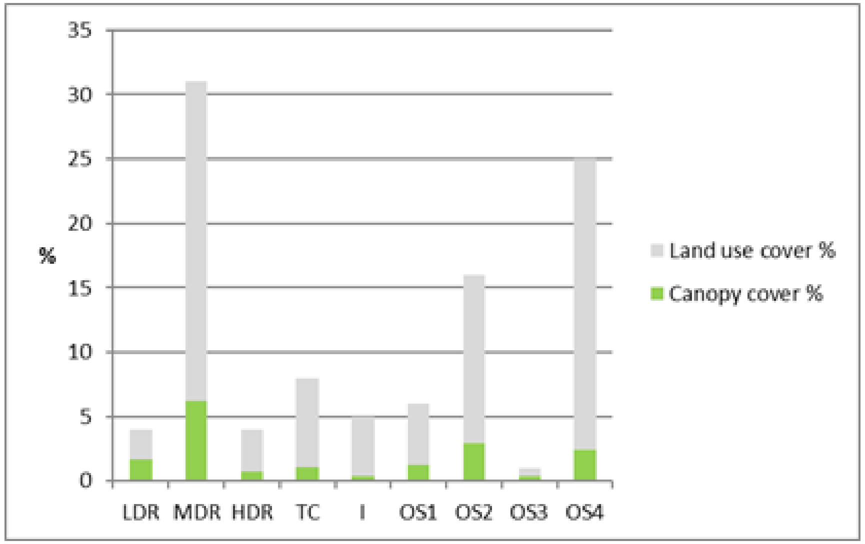


Figure 7 Protected trees



Key

LDR – LOW DENSITY RESIDENTIAL

MDR – MEDIUM DENSITY RESIDENTIAL

TC – TOWN CENTRE

I – INDUSTRIAL

OS1 – FORMAL OPEN SPACE

OS2 – INSTITUTIONAL OPEN SPACE

OS3 – DERILICT OPEN SPACE

OS4 – REMNANT AGRICULTURAL LAND

Figure 8 Absolute canopy cover by land use

Table 1 Ownership by canopy and land area

Ownership	Canopy cover (%)	Land area (%)
City Council	16.3	13.5
Highway	9.6	9.5
Private/other	74.1	77

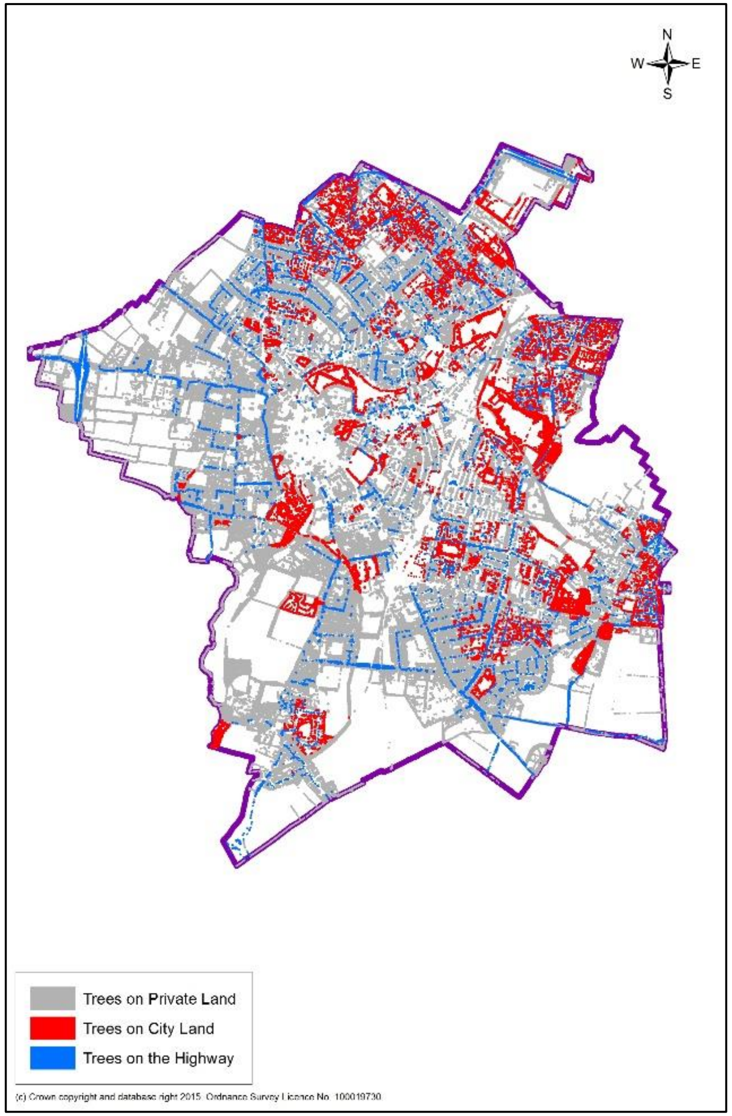


Figure 9 Distribution of canopy by ownership

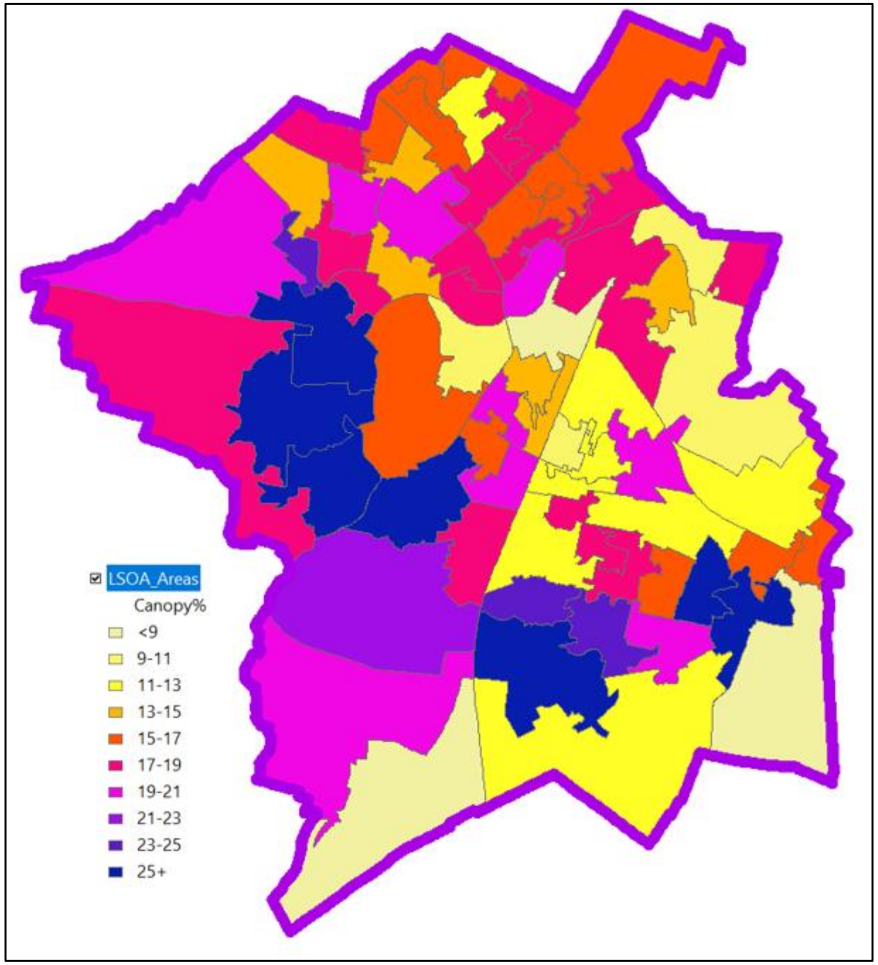


Figure 10 Canopy cover by LSOA using 2008 data

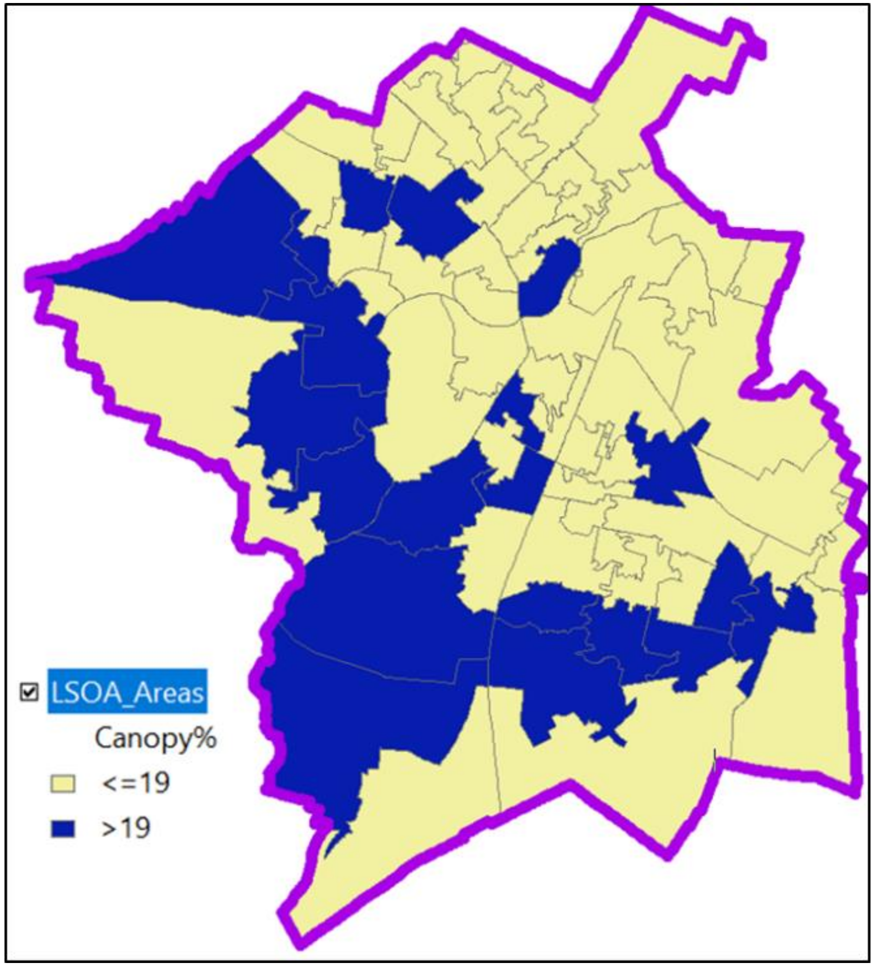


Figure 11 Tree canopy by LSOA - target areas, using 2008 data

Climate change in Cambridge

There is little in the way of specific data of how climate change might impact Cambridge, but the increasing intensity of summer temperature extremes and more frequent storm events are expected to become the norm, resulting in increased heat stress and storm water flooding. These increases will be directly as a result of a changing climate and will be indirectly exacerbated as a result of the projected increase in built infrastructure in the City, acting as a heat store and increasing storm water run-off. Regional projections are available.

In 2009 the UK Climate Projections (UKCP09) programme provided projections of how the climate will change in the East of England and other regions, based on low, medium and high emissions scenarios. The data from this programme suggests that by 2080 the East of England will experience:

- Increases in average summer temperatures of 1.3 - 4.7°C under a low emissions scenario, and 2.4 - 7.5°C under a high emissions scenario.
- Increases in average winter precipitation of 16% under a low emissions scenario and 26% under a high emissions scenario.
- Reductions in average summer precipitation of 14% under a low emissions scenario and 27% under a high emissions scenario (Murphy et al., 2009).

In the most recent 2018 UK Climate Change Projections (UKCP18) update, it is stated that hot summers are expected to become more common: 'In the recent past (1981-2000) the chance of seeing a summer as hot as 2018 was low (<10%). The chance has already increased due to climate change and is now between 10-20%. With future warming, hot summers by mid-century could become even more common (~50%)' (Murphy et al., 2018).

This summer (2019) Cambridge experienced the hottest temperature (38.7°C) yet recorded in the UK[5].

Key challenges facing the urban forest in Cambridge

The key challenges facing the urban forest and its management in the City are climate change, pests and diseases, and water scarcity. These are inter-related factors that affect the health of trees. Additionally, increasing urbanisation of cities can compete with the urban forest for space. Further, trees in urban settings can cause real and significant problems for people, and this should be recognised as a significant challenge to planning urban forests.

The changing climate presents both benefits and risks to the trees themselves. Increases in carbon dioxide and warmer temperatures will lead to improved growth rates and longer growing seasons. Conversely, increased storm frequencies and summer drought will lead to increased damage to, and losses of, trees.

It is likely that climate change will exacerbate the impact of existing pests and diseases on trees. Hotter, drier summers for example, may stress individual trees, making them more susceptible to infection. Some of the most damaging tree pests and diseases have come from abroad (so called 'alien invasive species'), often causing little trouble in their native habitats. Some of these organisms can be virulent, fast-spreading, and unstable when introduced to the UK, which has few of the

[5] https://www.bbc.co.uk/news/uk-49157898

environmental or biological controls that keep them in check in their native habitats. Ash Dieback Disease for example, is present in Cambridge's ash population, which represents 22% of the tree population by number. Ash (*Fraxinus excelsior*) is a large species tree that is native to the UK. Ash trees freely self-seed and could be considered a boon to urban forest sustainability. It has been reported that the disease will likely result in 95% mortality in the entire Ash population (Anderson, 2019). This will have a significant impact on the tree canopy cover and urban forest of Cambridge as a whole, and to the majority of woodlands across the UK. It has been estimated that the impact resulting from Ash dieback will cost the UK £15 billion (Hill et al., 2019).

The East of England region is the driest region in the country. Annual rainfall is only 70% of the national average (Climate UK, 2012). This situation will become worse with a changing climate, consequently impacting on tree health, their ability to provide optimum ecosystem service delivery, and increasing the cost of tree establishment through planting programmes. These issues can be managed to some extent both by species selection and looking for opportunities to improve the water cycling in the City through grey and green water collection and usage.

Cambridge is experiencing significant population growth. Increases in population, both permanent and non-permanent, will increase pressures on public spaces to accommodate more uses – whether for recreation in parks, for more roadside parking, or higher housing densities – which can result in direct competition with new tree planting for space, as well as making growing conditions more demanding, due to more extensive hard or compacted surfaces. High density housing, if provided with a good amount of green space, can have advantages for biodiversity over more traditional low-density housing with gardens (Collas et al., 2016). However, there is a trade-off, as trees in individual gardens can bring greater health and well-being benefits (Cox et al., 2019). High density housing brought about by infill development offers little benefit both to biodiversity, and health and well-being (Collas et al., 2019).

The urban forest can also have negative effects on human well-being. Some of the problems resulting from urban forests include increased ground-level ozone concentrations, the blocking of light and heat, tree root-induced damage to infrastructure, risk of injury or damage from tree or branch fall, and pollen-associated allergic reactions. It has been suggested that for urban forests to better help, it is necessary to address the information gap on the nature and extent of each local authority's urban forest, and to conduct further research on decision support systems which improve understanding of ecosystem services and the associated economic benefits brought about by trees (Davies et al., 2017b).

PART 2

Key drivers

Building climate resilience is the overriding objective of the project. There are many ways in which the urban forest can contribute to this: sequestering and storing carbon; regulating urban temperatures; attenuating storm water; purifying air; saving energy used to cool buildings; and protecting infrastructure from extremes of temperature. Biodiversity can also be adversely impacted by a changing climate, whilst the nature conservation value of the urban forest can vary depending on species and location, its structure and distribution forms an interconnected network that supports linkages between areas of higher value and offers physical protection by regulating climate in the wider context of the City (Figure 5). In response to this range of drivers and associated problems, the project will focus on heat stress and storm water attenuation as the key drivers for this investment pilot.

The expansion of impermeable surfaces in the urban environment increases the surface water flow entering sewers, and climate change is likely to exacerbate this problem. This increases the risk of systems overloading in sustained rainfall events and potentially causing pollution of watercourses. By transferring water rapidly away from where it falls there is also the possibility of a receiving watercourse being inundated and causing flooding (Local Government Association, 2019). Urban trees can help mitigate against surface water flooding by both reducing the amount storm water reaching drainage systems and by slowing its flow to them. Trees intercept and store rainfall on their leaves, which either subsequently evaporates or reaches the ground more slowly as a result of its gradual release as throughfall. Trees also improve infiltration into the soil by channelling water down the stem and through the soil along root channels (Davies et al., 2017b). Infiltration into compacted soils with trees present is greater than when compared to compacted soils without trees. Trees can also create a physical obstacle to the path of surface water that helps to slow its flow to drains and other natural channels. Greater canopy cover is effective at increasing rainfall interception. For instance, taller trees (~30 m) can reduce the amount of rainfall converted into throughfall compared to that of smaller trees (~10 m). Furthermore, flooding can be further decreased, and groundwater recharge increased, when trees are located next to roads and rivers.

In the next few decades temperatures in Cambridge are predicted to rise due to climate change, as is the density of development. High temperatures can be a threat to health and well-being and can decrease thermal comfort. Materials such as asphalt, tarmac, and brick absorb sunlight and store more heat than vegetation (which reflects more radiation). This absorption results in warmer air temperatures over urban areas compared to those over rural areas. This ‘urban heat island’ effect is more pronounced during heatwaves – heat-related stress already accounts for around 1,100 premature deaths per year in the UK. Trees are not only good reflectors of short-wave radiation, but their canopies also shade darker surfaces that would otherwise absorb such radiation; reducing surface temperatures and convective heat (see Figure 12 for the range of heat related benefits provided by trees). Trees also reduce warming of the local environment through the process of evapotranspiration where, by the evaporation of water from leaf surfaces, cools the surrounding air and improves human thermal comfort (Davies et al., 2017b)[6]. Trees not only reduce temperatures, but also filter and block radiant heat from direct sunlight. This is important in helping to reduce sunburn and skin cancer. Children's skin is particularly sensitive to damage from UV rays, and the amount of sun exposure during childhood is thought to increase the risk of developing skin cancer in later life. This makes shading from trees particularly important in school grounds, parks, gardens, and other places where children play, helping to reduce the harmful effects of UV radiation and encourage active lifestyles.

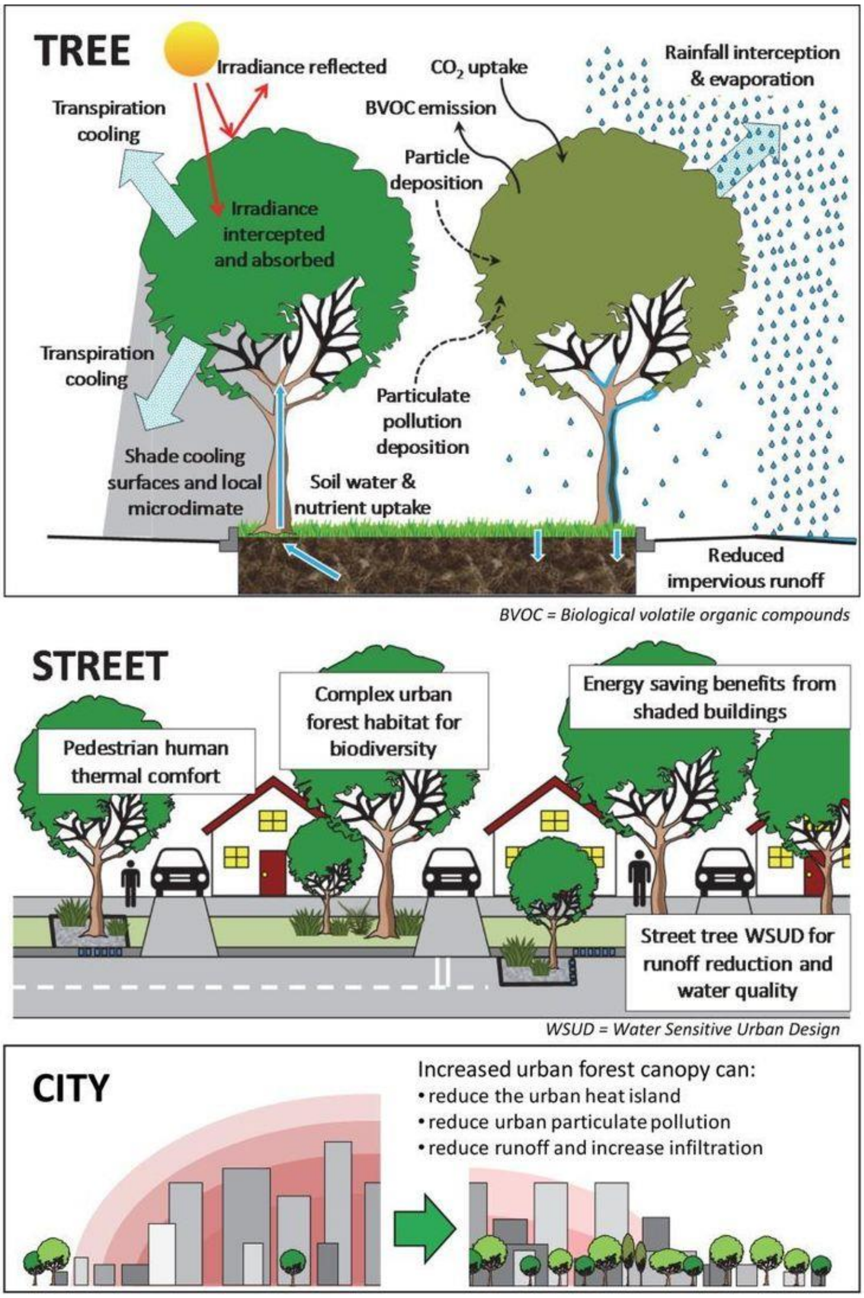


Figure 12 How tree mitigate flood and heat risk (Livesley et al., 2016)

[6] A large tree can lose 450 litres of water to the atmosphere per day through transpiration. In doing so, it will consume 1,000 megajoules of heat energy to drive the evaporation processes involved in transpiration. In effect, this energy consumption acts to lower summer air temperatures in the direct vicinity around trees (UK NEA, 2011).

Where to plant or protect trees?

Across the City there are numerous opportunities available for potential tree planting; an overview is presented in Table 2 Opportunities for tree planting and protection below.

Table 2 Opportunities for tree planting and protection

Scale and management	Opportunities to plant and/or protect
City	At a citywide scale Cambridge is a matrix of areas of high and low tree canopy cover (Figure 3, Figure 10 & Figure 11). The totality of the urban forest provides cooling, storm water attenuation, and air purification services. The good level of tree cover in the south west of the City provides cooling from the prevailing summer winds to the rest of Cambridge (Figure 6 & Figure 11). In the east of the City, green space provision is low. Planting trees here may help improve access to green infrastructure (Figure 5).
Open spaces (including institutional open space)	Many of Cambridge's open spaces currently have poor tree cover. These open spaces could provide islands of high-quality tree cover and their associated benefits (Figure 5). Outdoor activities in extremes of heat and solar radiation may be limited by lack of shade provision. By increasing opportunities for individuals to regulate their temperature and protect themselves from UV through shading, open spaces are more likely to be used in these conditions. Open spaces have the capacity to accommodate large species trees that provide greater flows of ecosystem services than small species trees. They also have the capacity to accommodate higher levels of tree cover than many other land uses, extending their potential for ecosystem service delivery further.
Streets	Streets form an essential network of linear corridors throughout the City, connecting citizens with their homes, services, and workplaces. Streets which are unprotected by shading from adjacent buildings or tree cover can be thermally uncomfortable in extremes of weather. There are opportunities to improve the thermal comfort and UV protection afforded to residents, pedestrians, and cyclists which would encourage more sustainable forms of transport. There are also opportunities to reduce flooding and increase groundwater recharge through tree planting in streets (Figure 9).
Gardens	Gardens make up a large proportion of the land use in Cambridge*. Trees in gardens form a matrix of canopy cover across the City, through which streets run and parks sit. Depending on their size, gardens provide an excellent opportunity for planting trees of all sizes. Most housing in Cambridge is classified as 'medium density residential'; this housing stock can generally accommodate small (up to 6m) or medium sized trees (up to 12m in height after 25 years). The opportunity for garden level tree planting, and the potential cumulative benefits which it could bring about are considerable. Increased tree numbers in gardens would provide continuity of canopy cover from street to street and would provide

	the most direct and meaningful benefit to the individual resident (family) who lives in that property (Figure 8 & Figure 9). **Office for National Statistics data on housing (ONS, 2011) found 57,304 dwelling in Cambridge, of which 70% (40,113) were either detached, semi-detached or maisonettes, and are assumed to have gardens.*

Much literature is available on the design principles for tree planting and urban forestry to achieve various desired outcomes. Figure 13 and Figure 14 for example, set out such principles in relation to maximising the benefits derived from tree planting regarding the mitigation of urban heat island effects. Planting activities carried out as part of the project will take on board guidance such as this, wherever and whenever practical and possible.

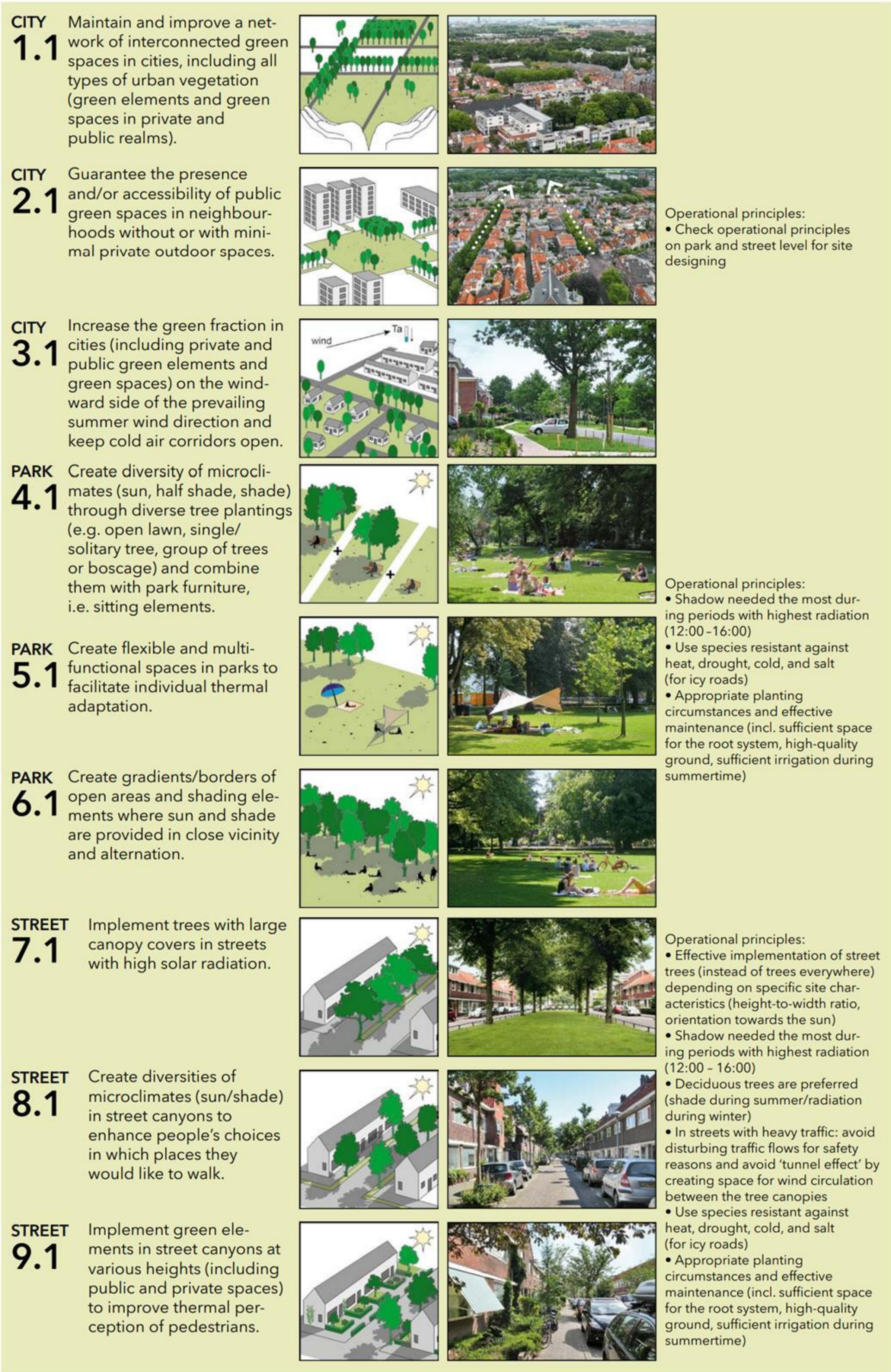


Figure 13 Design Principles to mitigate heat risk (taken directly from Klemm et al., 2017)

Figure 14 Residential design principles to mitigate heat risk (Forest Research, 2013)

PART 3

Aim and main objectives of the investment

The aim describes the advantage of carrying out the investment; it indicates the change which the investment is aiming to bring about, whilst the main objective of the project provides the overall context for what the investment is trying to achieve. It relates to the strategic aspects of the investment.

The aim of the investment is:

- **To help the City adapt to a changing climate by cultivating a resilient urban forest with increased tree canopy cover of 2% (17% rising to 19%) by the 2050's.**

The main objectives of the investment are:

- **To contribute to, and encourage, increased levels of tree planting and protection.**
- **To make a measurable contribution to the sustainability of the City's urban forest.**

Project scope

The project is naturally limited by time and resource. It will fund further analysis of the structure, distribution and composition of the urban forest in the first year allowing us to deliver the main project activities (e.g. increased tree planting – c. 650 trees per year, protection and engagement) over the last three years of the project. High cost solutions (such as engineered tree pits in streets and roads, or block planting on some open spaces) would involve lengthy decision-making processes that are outside of the scope of this investment, except where the opportunity arises in other Council activities or in special circumstances (e.g. where there is overriding public support for specific schemes). The investment will prioritise low cost and/or easy decision-making planting opportunities in the public realm. It will also focus its engagement activities on areas of low canopy and high need for tree benefits – engaging with residents, businesses, schools, and organisations with mutual objectives.

Whilst the projects focus is primarily aimed at achieving the 'easy wins' as set out above, by collecting and analysing data on the existing urban forest we will also seek to create an enhanced evidence base to support higher cost solutions to tree planting and protection (i.e. policy development). In so doing, we will seek to expand the opportunity to maximise tree canopy cover and ecosystem service delivery in the City.

Specific objectives, main outputs and specific results

The project's specific objectives are concrete statements describing what the investment is trying to achieve, and refer to the main outputs of the investment. It will be possible to evaluate the efficacy of the main outputs at the conclusion of the investment, and these will be seen as the core products of the investment. The main outputs directly contribute to the achievement of the overall aim and related specific results.

The following urban forest management approaches help define the specific objectives, main outputs, and activities of the project.

1. **Manage more**
   Any activity that improves resources (including knowledge, finance, or human) that in turn facilitates better or greater engagement, protection, and planting approaches.
2. **Plant more**
   Any activity leading to increased numbers of trees being planted in the ground.
3. **Protect more**
   Any activity leading to the enhanced care, maintenance, safeguarding, and retention of trees (including statutory protection e.g. TPOs).
4. **Engage more**
   Any activity taking place with stakeholders that seeks to support the management, protection, and planting approaches above.

Specific objectives (SOs)

1. **Manage more**
   To improve understanding of the structure, composition, distribution, dynamics, and value of the urban forest in order to further develop and enable it to provide support for the challenges we will confront in the face of a changing climate.
2. **Plant more**
   To partner with stakeholders at all levels to support new tree planting.
3. **Protect more**
   To protect trees of current and future amenity value in areas where statutory tree protection is currently low.
4. **Engage more**
   To foster a collaborative approach to urban forest management.

Main outputs (MOs)

1. **More management**
   An open and accessible framework of data and guidance that will inform the planting and protection of the urban forest and support wider engagement.
2. **More planting**
   Vacant tree locations on City Council managed land planted.
   An increase in planting brought about by engagement activities on land not managed by the City Council.
3. **More protection**
   Increased protection by TPO of privately-owned tree canopy in areas where there is currently low statutory protection.

Increased protection delivered and facilitated through management and engagement advice and activities.

4. **More engagement**

   New planting and outreach programme developed which targets areas of low canopy and high need for tree benefits.

   Increased stakeholder involvement in urban forestry.

Specific results

Specific results are the immediate benefits realised en route to achieving or producing a main output. The specific results and how they relate to the main outputs (MOs) are detailed in Table 3 below.

Table 3 Specific results

Specific result	MO1	MO2	MO3	MO4
Urban tree canopy cover assessments undertaken	x		x	
Urban tree canopy prioritisation assessments undertaken	x		x	
Decision support tool developed and disseminated	x	x	x	x
Tree planting and management guidance for householders produced	x	x	x	x
2,000 trees planted in Council managed lands		x		
Identify areas of low tree protection, develop strategy and implement to increase statutory protection			x	
Neighbourhood canopy scheme developed and implemented		x		x
Sponsors engaged				x
Partners engaged				x
i-tree eco urban tree canopy/ecosystem service valuation study undertaken	x			x
Stewardship programme developed	x			x

PART 4

Activities

Activities are tasks related to the specific objectives and are undertaken in order to achieve the main outputs; these are set out in detail in Table 4 below.

Table 4 Project activities

#	Category	Brief description	SO	MO
1	Urban Tree Canopy Cover Assessments (UTCCA)	Analysis of the urban forest showing tree canopy cover at city, ward, LSAO, and OA[7] levels for 2018 data (to include structure, composition, and distribution)	1,3	1,3
2	UTCCA	Analysis showing rate of tree canopy cover change at city, ward, LSOA, and OA levels between 2008 &2018	1,3	1,3
3	UTCCA	Analysis showing the amount of tree canopy cover over roads, streets, and footpaths to promote shaded routes for thermal comfort and UV protection (e.g. see the Shadeways project[8])	1,3	1,3
4	Urban tree canopy prioritisation (UTCCP)	An assessment of needs relating to delivery of ecosystem services for the well-being of people in the City. To include possible canopy cover[9] assessments and other social, financial, and economic variables measured at LSOA level.	1,3	1,3
5	Decision support tool	Using the results of Activities 1-4 above, a decision support tool will be developed. This aims to provide guidance for decision makers at all levels (i.e. homeowner to large-scale landowner and/or managers) regarding tree protection and planting.	1,2,3,4	1,2,3,4
6	Guidance	Development of a tree planting and maintenance guide to promote planting and engagement in the urban forest	1,2,3,4	1,2,3,4

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[7] Lower Layer Super Output Areas (LSOAs) are a geographic hierarchy designed to improve the reporting of small area statistics in England and Wales. LSOAs are built from groups of Output Areas (OAs) and have been automatically generated to be as consistent in population size as possible, and typically contain from four to six OAs. The Minimum population is 1,000 and the mean is 1,500. There are 39 LSOAs and 349 OAs in Cambridge.

[8] https://www.shadeways.net/

[9] Possible planting positions are those where is it biophysically feasible to plant trees. This will be the first step in the assessment process. It is not concerned with costs, logistics or the fact that tree planting may not be appropriate or desirable in some locations. All land that is not covered by water, a road, or a building will be considered as a "possible" planting location.

#	Category	Brief description	SO	MO
7	Council restocking	The Council estimates it has ~2,000 vacant tree locations that could be replanted. Using the decision support too developed in Activity 5 above, locations for large species tree planting will be identified	2	2
8	TPO strategy	Using the results of the UTCCA, a strategy will be developed to assist the identification and protection of high amenity value trees in areas with low levels of existing protection	3	3
9	Neighbourhood canopy campaign	A localised and high activity campaign will be designed and rolled out to engage as many stakeholders (residents, schools, businesses) in the area as possible to plant trees on private property, or to sponsor tree planting, in order to increase tree canopy cover in the targeted neighbourhood area. The specific neighbourhood areas will be prioritised using the decision support tool (see Activity 5 above) and may also be themed to increase sponsor engagement (e.g. by ecosystem service type).	2,4	2,4
10	i-tree eco project[10]	An ecosystem service valuation project will be run which will seek to involve citizens	1, 4	1, 4
11	Stewardship programme	A citizen engagement programme to help us manage our own trees (e.g. help-us-water scheme) and collect data (e.g. ash survey to collect data of the distribution of ash in Cambridge) will be initiated	1,4	1,4

[10] https://www.itreetools.org/tools/i-tree-eco

PART 5

Annex 1 Ecosystem services provided by urban forests

Whilst tree canopy cover management can only be part of the solution to helping urban areas adapt to climate change, it has the advantage of being relatively low cost and easy to implement in comparison to many other engineered solutions. The use of trees as part of a green infrastructure based approach to climate change adaptation and mitigation also has the advantage of providing multiple benefits beyond just storm water attenuation and temperature regulation – as detailed in Table 5 below.

Table 5 List of ecosystem services provided by the urban forest arranged according to the Millennium Ecosystem Assessment categories of ecosystem services. Ecosystem services which mitigate the key drivers of the investment are in bold (Davies et al., 2017b)

Provisioning	Regulating	Supporting	Cultural
Food	Carbon sequestration and storage	Soil formation	**Health and well-being**
Fuel	**Temperature regulation**	Biodiversity	Nature and landscape connections
Wood	**Storm water attenuation**	Oxygen production	Social development and connections
	Air purification		Education and learning
	Noise mitigation		Economy and cultural significance

<u>Millennium Ecosystem Assessment categories (Armour et al., 2012)</u>

Supporting services

The services that are necessary for the production of all other ecosystem services, including soil formation, photosynthesis, primary production, nutrient cycling, and water cycling.

Provisioning services

The products obtained from ecosystems, including food, fibre, fuel, genetic resources, biochemicals, natural medicines, pharmaceuticals, ornamental resources, and fresh water.

Regulating services

The benefits obtained from the regulation of ecosystem processes, including air quality regulation, climate regulation, water regulation, erosion regulation, water purification, disease regulation, pest regulation, pollination, and natural hazard regulation.

Cultural services

The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences, taking account of landscape values.

Annex 2 How Cambridge's tree canopy cover compares with other similar districts

The amount of tree canopy cover in an urban area depends on many different variables, including climate, geology, population, built form and density, land use type, age of primary development, and social and economic factors. This can make comparisons extremely difficult to interpret. Where data has been available, a list of five towns and cities of similar size, population, and land uses have been selected for comparison below (Table 6).

Table 6 District canopy cover comparisons

District	Area (km^2)	Population[1]	Population density (per km^2)[2]	Green urban %[3]	Farmland %[3]	Natural %[3]	Built on %[3]	Tree cover (%)[4]	Source[4]
Cambridge	40.70	124,900	3,069	17	26	0	58	17.1	Proximitree™
Exeter	47.04	128,900	2,740	14	29	7	50	18.8 - 23	i-Tree Canopy
Gloucester	40.54	129,000	3,183	17	15	2	66	13.6	i-Tree Canopy
Ipswich	39.42	138,600	3,505	19	17	<1	64	11.0	i-Tree Canopy
Oxford	45.59	154,600	3,389	14	31	1	53	16.6 - 21.4	i-Tree Canopy

Data sources:

1. List of English districts by population Last accessed 21/5/19
2. List of English districts by population density Last accessed 21/5/19
3. BBC How much is your area built on Last accessed 21/5/19
4. Doick, K., et al (2017) The Canopy Cover of England's Towns and Cities: baselining and setting targets to improve human health and well-being

Annex 3 Opportunities for tree planting in city wards

Extracted from section 7.2.3 of the 2013 ADAS report 'Analysis and interpretation of tree audit data in Cambridge City Council' [PDF, 6.3MB] https://www.cambridge.gov.uk/sites/default/files/analysis-and-interpretation-of-tree-audit-data.pdf)

Abbey is dominated by Medium Density Residential (MDR), Formal and informal/amenity land (OS1) and Institutional Open Space (OS2) land. There are therefore opportunities for increasing canopy cover in this ward by encouraging garden planting in MDR, planting tree species with larger canopy spreads in OS1 and encouraging institutions to plant larger trees in OS2.

Arbury consists largely of MDR land-use and there are therefore opportunities for increasing canopy cover by encouraging homeowners to plant suitable tree species in their gardens.

Castle is dominated by OS2 and Remnant Countryside (OS4) land. Institutions and agricultural landowners should be encouraged to plant specimens that will have large canopies in these open spaces wherever possible. Castle ward already has one of the greatest representative tree canopy sizes in the City due to the abundance of OS2 and OS4 land, which also have high representative tree canopy sizes.

Cherry Hinton is dominated by OS4 and MDR land-uses. Homeowners and agricultural landowners should be encouraged to plant appropriate species wherever possible.

Coleridge consists largely of MDR land-use and there are therefore opportunities for increasing canopy cover by encouraging homeowners to plant suitable tree species in their gardens.

East Chesterton is dominated by MDR and Industrial land-uses. There are therefore opportunities for increasing canopy cover in this ward by encouraging garden planting in MDR and targeting Highways and City centre industrial sites for planting.

King's Hedges consists largely of MDR land-use and there are therefore opportunities for increasing canopy cover by encouraging homeowners to plant suitable tree species in their gardens.

Market comprises Town Centre land-use and OS1. There are limited opportunities for planting in the City centre, although any trees planted here will have beneficial effects with respect to the urban heat island. There are opportunities to plant species with larger canopy spreads in OS1, however Market already has the highest representative tree canopy size of all the wards since OS1 has the highest representative tree canopy size of all land-uses.

Newnham largely consists of OS2 and OS4 land-use categories. Institutions and agricultural landowners should be encouraged to plant specimens that will have large canopies in these open spaces wherever possible. Newnham ward already has one of the greatest representative tree canopy sizes in the City due to the abundance of OS2 and OS4 land, which also have high representative tree canopy sizes.

Petersfield has the majority of its land in MDR, but also has fairly high representation of HDR, Town Centre, Industrial and OS2. Opportunities exist for increasing canopy cover particularly in High Density Residential (HDR) and OS2 land-uses.

Queen Edith's has the highest proportion of Low Density Residential (LDR) of any ward and the majority of the remainder is split between MDR, OS2 and OS4. The best opportunities for increasing canopy cover exist in the open space categories.

Romsey has the vast majority of its land area in MDR. There are therefore opportunities for increasing canopy cover by encouraging homeowners to plant suitable tree species in their gardens.

Trumpington is dominated by OS4 land use. It also has one of the highest representative tree canopy sizes in the City because of this. There may be scope for encouraging landowners to plant larger species at the boundaries of their agricultural fields.

West Chesterton consists largely of MDR land-use and there are therefore opportunities for increasing canopy cover by encouraging homeowners to plant suitable tree species in their gardens.

References

ADAS (2013). Analysis and interpretation of tree audit data in Cambridge City Council [PDF, 6.3MB] https://www.cambridge.gov.uk/sites/default/files/analysis-and-interpretation-of-tree-audit-data.pdf

Anderson, H. (2019). Ash dieback is predicted to cost £15 billion in Britain. Article dated 6 May 2019. https://www.woodlandtrust.org.uk/press-centre/2019/05/ash-dieback-predicted-to-cost-15-billion/.

Armour, T., Job, M. and Canavan, R. (2012). *The Benefits of Large Species Trees in the Urban Landscape: A Costing, Design and Management Guide.* CIRIA, London, UK.

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

Cambridge City Council (2016a). Cambridge Citywide Tree Strategy 2016-2026. Available to download from: https://www.cambridge.gov.uk/tree-strategy

Cambridge City Council (2016b). Climate Change Strategy 2016-2021 https://www.cambridge.gov.uk/climate-change-strategy

Climate UK (2012). A summary of climate change risks for the East of England. To coincide with the publication of the UK Climate Change Risk Assessment (CCRA) 2012.

Collas, L.; Green, R.E.; Ross, A.; Wastell, J.H.; and Balmford, A. (2016). Urban development, land sharing and land sparing: the importance of considering restoration. UK Climate Change Risk Assessment 2017 Synthesis report: priorities for the next five years. Committee on Climate Change, London.

Cox, D.T.C., Benniec, J., Casalegno, S., Hudson, H.L., Anderson, K., Gaston, K.J. (2019). Skewed contributions of individual trees to indirect nature experiences .Landscape and Urban Planning 185 (2019) 28–34

Davies, H., Doick, K., Handley, P., O'Brien, L., and Wilson, J. (2017b). *Delivery of ecosystem services by urban forests* Forestry Commission Research Report Forestry Commission, Edinburgh. i–iv + 1–28pp.

Davies, H.J., Doick, K., Hudson, M., Schreckenberg, K. (2017a). Challenges for tree officers to enhance the provision of regulating ecosystem services from urban forests. Environmental Research 156, pp 97–107

Doick, K., et al (2017). The Canopy Cover of England's Towns and Cities: baselining and setting targets to improve human health and well-being. https://www.researchgate.net/publication/322337570_The_Canopy_Cover_of_England's_Towns_and_Cities_baselining_and_setting_targets_to_improve_human_health_and_well-being. Last accessed 21/5/19.

European Commission (2015). Nature-Based Solutions and Re-Naturing Cities: Final Report of the Horizon 2020 Expert Group. European Commission, Brussels.

FAO (2016). Guidelines on urban and peri-urban forestry, by F. Salbitano, S. Borelli, M. Conigliaro and Y. Chen. FAO Forestry Paper No.178. Rome, Food and Agriculture Organization of the United Nations.

Forestry Commission (2010). *The case for trees*. Bristol: Forestry Commission.

Grove, M. J., et al (2006). A report on New York City's present and possible tree canopy cover.

Hand, K. L., Doick, K. J. and Moss, J. L. (2019). *Ecosystem services delivery by large stature urban trees*. Research Report. Forest Research, Edinburgh i–iv + 1–24pp.

Hill, L., Jones, G., Atkinson, N., Hector, A., Hemery, G., & Brown, N. (2019). The£ 15 billion cost of ash dieback in Britain. Current Biology, 29(9), R315-R316.

Klemm, W., Lenzholzer, S. and Brink, v.d. A. (2017). Developing green infrastructure design guidelines for urban climate adaptation. Journal on Landscape Architecture 12 (3), 60-71.

Leff, M. (2016). A sustainable urban forest. A step-by step approach. Davey Institute. USDA Forest Service.

Livesley, S.J., McPherson, G.M. and Calfapietra, C. (2016). The Urban Forest and Ecosystem Services: Impacts on Urban Water, Heat, and Pollution Cycles at the Tree, Street, and City Scale. Journal of Environmental Quality, 45(1), pp.119-124.

Local Government Association (2019). Surface water (pluvial) flooding. https://www.local.gov.uk/topics/severe-weather/flooding/flood-and-coastal-erosion-risk-management/surface-water-pluvial. Web page last accessed 04/08/19

Locke, D.H.; Grove, J.M.; Galvin, M.; O'Neil-Dunne, J.P.M.; Murphy, C. (2013). Applications of Urban Tree Canopy Assessment and Prioritization Tools: Supporting Collaborative Decision Making to Achieve Urban Sustainability Goals. Volume 6, Issue 1, Urban Forestry Practitioners Share All.

Lowry, J.; Baker, M.E.; Ramsey, R.D. (2012). Determinants of urban tree canopy in residential neighborhoods: Household characteristics, urban form, and the geophysical landscape. Urban Ecosystems 15 (1), 247–266.

Millennium Ecosystem Assessment (2005). Ecosystems and human well-being: A framework for assessment. Washington, D.C., US

Murphy J.M., Harris G.R., Sexton D.M.H., Kendon E.J., Bett P.E., Brown S.J., Clark R.T., Eagle K., Fosser G., Fung F., Lowe J.A., McDonald R.E., McInnes R.N., McSweeney C.F., Mitchell J.F.B., Rostron J., Thornton H.E., Tucker S., and Yamazaki K. (2018) UKCP18 Land Projections: Science Report. Met Office Hadley Centre, Exeter.

Murphy, J.M., Sexton, D.M.H., Jenkins, G.J., Boorman, P.M., Booth, B.B.B., Brown, C.C., Clark, R.T., Collins, M., Harris, G.R., Kendon, E.J., Betts, R.A., Brown, S.J., Howard, T. P., Humphrey, K. A., McCarthy, M. P., McDonald, R. E., Stephens, A., Wallace, C., Warren, R., Wilby, R., Wood, R. A. (2009). UK Climate Projections, Science Report: Climate change projections. Met Office Hadley Centre, Exeter.

Nicholson R. (2012). Tree management policy, Arboricultural Journal: The International Journal of Urban Forestry, 34:1, 17-28

Office for National Statistics (2011). 2011 Census data. Available at https://www.ons.gov.uk/census/2011census. Last accessed 27/11/19

UK Government (2019). Long term flood risk information. https://flood-warning-information.service.gov.uk/long-term-flood-risk/map. Last accessed 12/06/19.

UK National Ecosystem Assessment (2011). The UK National Ecosystem Assessment Technical Report. UNEP-WCMC, Cambridge.