

# Selecting urban trees for ecosystem service provision

## Supplementary Material

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This document contains further information and data presented in the FR In Brief report by Hand & Doick 2021. Selecting urban trees for ecosystem service provision. Available at: [forestresearch.gov.uk/research/urban-tree-benefits/es-provision](https://forestresearch.gov.uk/research/urban-tree-benefits/es-provision).

## Table of Contents

Table of Contents .....	1
Table of Figures .....	1
1 Growth Rate.....	2
Table 1. Urban tree growth rates from the literature .....	3
2 Ecosystem service provision over time .....	11
3 Location .....	14
4 Total ecosystem service provision .....	16
References .....	17

## Table of Figures

Figure 1. Average carbon stored by trees over time.....	11
Figure 2. Average carbon stored per year.....	11
Figure 3. Average avoided runoff by trees over time.....	12
Figure 4. Average pollution removal by trees over time.....	12
Figure 5. Average amenity (CAVAT) by trees over time.....	13

Figure 6. Ecosystem service delivery by trees over time..... 13  
Figure 7. Indicative ecosystem service provision by trees in enclosed, semi-open,  
and open locations. .... 14  
Figure 8. Ecosystem service provision over 100 years normalised across all species  
in the study. .... 16

## 1 Growth Rate

Table 1 records the growth rates used to estimate growth for each stature (large, medium and small) and each leaf type (conifer, broadleaf) group. Full references for each study are listed at the end of the document. Growth rates are only recorded for studies where growth rates were estimated with a linear equation. The Max. age column indicates the highest age to which the growth rate was applied to. This number was either directly listed in the study or inferred from descriptions of the size of tree in each study.

Table 1. Urban tree growth rates from the literature

Study	Genus	Species	Common Name	Location	Equation type	Stature	Leaf type	Land use	Max. age	Growth rate (cm/year)
Wood 2010	Abies	concolor	White fir	USA	linear	Large	Conifer	Urban	34	0.94
Sjoman et al. 2012	Acer	campestre	Field maple	Romania & Moldova	linear	Medium	Broadleaf	Woodland	100	0.28
Willoughby et al. 2007	Acer	campestre	Field maple	UK	linear	Medium	Broadleaf	Woodland	15	0.37
McPherson et al. 2016	Acer	macrophyllum	Bigleaf maple	USA	cubic	Large	Broadleaf	Urban	94	
McPherson et al. 2016	Acer	platanoides	Norway maple	USA	cubic	Large	Broadleaf	Urban	115	
Willoughby et al. 2007	Acer	platanoides	Norway maple	UK	linear	Large	Broadleaf	Woodland	15	0.74
Vaz Monteiro et al. 2017	Acer	pseudoplatanus	Sycamore	UK	log	Large	Broadleaf	Urban	150	
McPherson et al. 2016	Acer	rubrum	Red maple	USA	linear	Large	Broadleaf	Urban	96	1.6
McPherson et al. 2016	Acer	saccharum	Sugar maple	USA	cubic	Large	Broadleaf	Urban	73	

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Buhler et al. 2007	Acer	spp.	Maple spp.	Denmark	linear	Large	Broadleaf	Urban	25	0.69
Sjoman et al. 2012	Acer	tataricum	Amur maple	Romania & Moldova	linear	Small	Broadleaf	Woodland	100	0.22
Willoughby et al. 2007	Alnus	cordata	Italian alder	UK	linear	Medium	Broadleaf	Woodland	15	0.705
Willoughby et al. 2007	Alnus	glutinosa	Alder	UK	linear	Medium	Broadleaf	Woodland	15	0.6
McPherson et al. 2016	Betula	pendula	Silver birch	USA	quadratic	Medium	Broadleaf	Urban	48	
Vaz Monteiro et al. 2017	Betula	pendula	Silver birch	UK	log	Medium	Broadleaf	Urban	120	
Willoughby et al. 2007	Betula	pendula	Silver birch	UK	linear	Medium	Broadleaf	Woodland	15	0.7
Willoughby et al. 2007	Betula	pubescens	Downy birch	UK	linear	Medium	Broadleaf	Woodland	15	0.9
McPherson et al. 2016	Calocedrus	decurrans	Incense cedar	USA	cubic	Large	Conifer	Urban	51	
Sjoman et al. 2012	Carpinus	betulus	Hornbeam	Romania & Moldova	linear	Medium	Broadleaf	Woodland	100	0.3
McPherson et al. 2016	Carpinus	betulus 'Fastigata'	Hornbeam	USA	cubic	Medium	Broadleaf	Urban	24	

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Sjoman et al. 2012	Carpinus	orientalis	Oriental hornbeam	Romania & Moldova	linear	Medium	Broadleaf	Woodland	100	0.22
Sjoman et al. 2012	Cornus	mas	Cornel	Romania & Moldova	linear	Medium	Broadleaf	Woodland	100	0.17
Willoughby et al. 2007	Cornus	sanguinea	Common dogwood	UK	linear	Small	Broadleaf	Woodland	15	0.24
Willoughby et al. 2007	Corylus	avellana	Hazel	UK	linear	Small	Broadleaf	Woodland	15	0.21
Buhler et al. 2007	Crataegus	x lavallei	Hybrid cockspur thorn	Denmark	linear	Small	Broadleaf	Urban	25	0.59
McPherson et al. 2016	Crataegus	x lavallei	Hybrid cockspur thorn	USA	cubic	Small	Broadleaf	Urban	38	
Sjoman et al. 2012	Crataegus	monogyna	Hawthorn	Romania & Moldova	linear	Small	Broadleaf	Woodland	100	0.22
Willoughby et al. 2007	Crataegus	monogyna	Hawthorn	UK	linear	Small	Broadleaf	Woodland	15	0.32
Wood 2010	Crataegus	monogyna	Hawthorn	USA	linear	Small	Broadleaf	Urban	34	0.43
Willoughby et al. 2007	x Cuprocypris	leylandii	Leyland cypress	UK	linear	Large	Conifer	Woodland	15	1.17

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McPherson et al. 2016	Fagus	sylvatica	Beech	USA	cubic	Large	Broadleaf	Urban	45	
Willoughby et al. 2007	Fagus	sylvatica	Beech	UK	linear	Large	Broadleaf	Woodland	15	0.51
Buhler et al. 2007	Fraxinus	excelsior	Ash	Denmark	linear	Large	Broadleaf	Urban	25	0.98
Sjoman et al. 2012	Fraxinus	excelsior	Ash	Romania & Moldova	linear	Large	Broadleaf	Woodland	100	0.38
Vaz Monteiro et al. 2017	Fraxinus	excelsior	Ash	UK	log	Large	Broadleaf	Urban	150	
Willoughby et al. 2007	Fraxinus	excelsior	Ash	UK	linear	Large	Broadleaf	Woodland	15	0.55
McPherson et al. 2016	Fraxinus	latifolia	Oregon ash	USA	linear	Large	Broadleaf	Urban	94	2.22
Iszkulo & Boratynski 2011	Juniperus	communis	Juniper	Poland	linear	Medium	Conifer	Woodland	50	0.64
Willoughby et al. 2007	Laburnum	anagyroides	Laburnum	UK	linear	Small	Broadleaf	Woodland	15	0.69
McPherson et al. 2016	Liquidamber	styraciflua	Liquidamber	USA	linear	Large	Broadleaf	Urban	68	1.6
McPherson et al. 2016	Malus	angustifolia	Southern crabapple	USA	quadratic	Medium	Broadleaf	Urban	21	

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Wood 2010	Malus	spp.	Crab apple spp.	USA	linear	Small	Broadleaf	Urban	34	0.99
McPherson et al. 2016	Morus	alba	White mulberry	USA	cubic	Medium	Broadleaf	Urban	45	
Wood 2010	Picea	pungens	Blue spruce	USA	linear	Large	Conifer	Urban	34	1.19
McPherson et al. 2016	Pinus	contorta	Lodgepole pine	USA	loglog	Large	Conifer	Urban	43	
Wood 2010	Pinus	ponderosa	Ponderosa pine	USA	linear	Large	Conifer	Urban	100	1.09
Buhler et al. 2007	Platanus	x acerifolia	London plane	Denmark	linear	Large	Broadleaf	Urban	25	1.01
Willoughby et al. 2007	Platanus	x acerifolia	London plane	UK	linear	Large	Broadleaf	Woodland	15	0.65
McPherson et al. 2016	Populus	balsamifera subsp. trichocarpa	Black cottonwood	USA	cubic	Large	Broadleaf	Urban	134	
Willoughby et al. 2007	Populus	canadensis	Canadian poplar	UK	linear	Large	Broadleaf	Woodland	15	1.99
Willoughby et al. 2007	Populus	tremula	Aspen	UK	linear	Large	Broadleaf	Woodland	15	0.85

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Buhler et al. 2007	Prunus	avium	Sweet cherry	Denmark	linear	Medium	Broadleaf	Urban	25	1.36
Willoughby et al. 2007	Prunus	avium	Sweet cherry	UK	linear	Medium	Broadleaf	Woodland	15	0.67
McPherson et al. 2016	Prunus	cerasifera	Cherry plum	USA	quadratic	Small	Broadleaf	Urban	21	
McPherson et al. 2016	Prunus	serrulata	Japanese cherry	USA	linear	Small	Broadleaf	Urban	49	1.8
McPherson et al. 2016	Pseudotsuga	menziesii	Douglas fir	USA	quadratic	Large	Conifer	Urban	109	
Willoughby et al. 2007	Pyrus	communis	Common pear	UK	linear	Small	Broadleaf	Woodland	15	1.1
Sjoman et al. 2012	Quercus	dalechampii	Dalechamp oak	Romania & Moldova	linear	Large	Broadleaf	Woodland	100	0.38
Sjoman et al. 2012	Quercus	frainetto	Hungarian oak	Romania & Moldova	linear	Large	Broadleaf	Woodland	100	0.36
Sjoman et al. 2012	Quercus	pubescens	Downy oak	Romania & Moldova	linear	Large	Broadleaf	Woodland	100	0.33
Sjoman et al. 2012	Quercus	robur	English oak	Romania & Moldova	linear	Large	Broadleaf	Woodland	100	0.43



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Vaz Monteiro et al. 2017	Quercus	robur	English oak	UK	log	Large	Broadleaf	Urban	150	
Willoughby et al. 2007	Quercus	robur	English oak	UK	linear	Large	Broadleaf	Woodland	15	0.58
McPherson et al. 2016	Quercus	rubra	Red oak	USA	cubic	Large	Broadleaf	Urban	66	
Buhler et al. 2007	Quercus	palustris petraea Robur rubra	Oak spp.	Denmark	linear	Large	Broadleaf	Urban	25	0.69
Buhler et al. 2007	Robinia	pseudoacacia	False acacia	Denmark	linear	Large	Broadleaf	Urban	25	1.15
Willoughby et al. 2007	Robinia	pseudoacacia	False acacia	UK	linear	Large	Broadleaf	Woodland	15	0.96
Willoughby et al. 2007	Salix	caprea	Goat willow	UK	linear	Small	Broadleaf	Woodland	15	0.52
Atkinson & Atkinson, 2002	Sambucus	nigra	Elder	UK	linear	Small	Broadleaf	Urban	101	0.4
Buhler et al. 2007	Sorbus	aria intermedia latifolia	Whitebeam spp.	Denmark	linear	Medium	Broadleaf	Urban	25	0.8

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Sjoman et al. 2012	Sorbus	torminalis	Wild service tree	Romania & Moldova	linear	Large	Broadleaf	Woodland	100	0.26
Hindson 2007	Taxus	baccata	Yew	UK	linear	Medium	Conifer	Urban	150	0.43
Piggot 1995	Taxus	baccata	Yew	UK	linear	Medium	Conifer	Urban	150	0.26
Willoughby et al. 2007	Thuja	plicata	Western redcedar	UK	linear	Large	Conifer	Woodland	15	1.45
McPherson et al. 2016	Tilia	americana	American lime	USA	cubic	Large	Broadleaf	Urban	69	
McPherson et al. 2016	Tilia	cordata	Small-leaved lime	USA	cubic	Large	Broadleaf	Urban	78	
Buhler et al. 2007	Tilia	cordata euroapaea platyphyllos	Lime spp.	Denmark	linear	Large	Broadleaf	Urban	25	0.85
Sjoman et al. 2012	Tilia	tomentosa	Silver lime	Romania & Moldova	linear	Large	Broadleaf	Woodland	100	0.46
McPherson et al. 2016	Ulmus	americana	American elm	USA	quadratic	Large	Broadleaf	Urban	139	

## 2 Ecosystem service provision over time

Figures 1 to 6 show the average provision of each benefit by species within each stature and leaf type group. The data used to produce these figures is available in the Excel workbooks associated with this supplementary material.

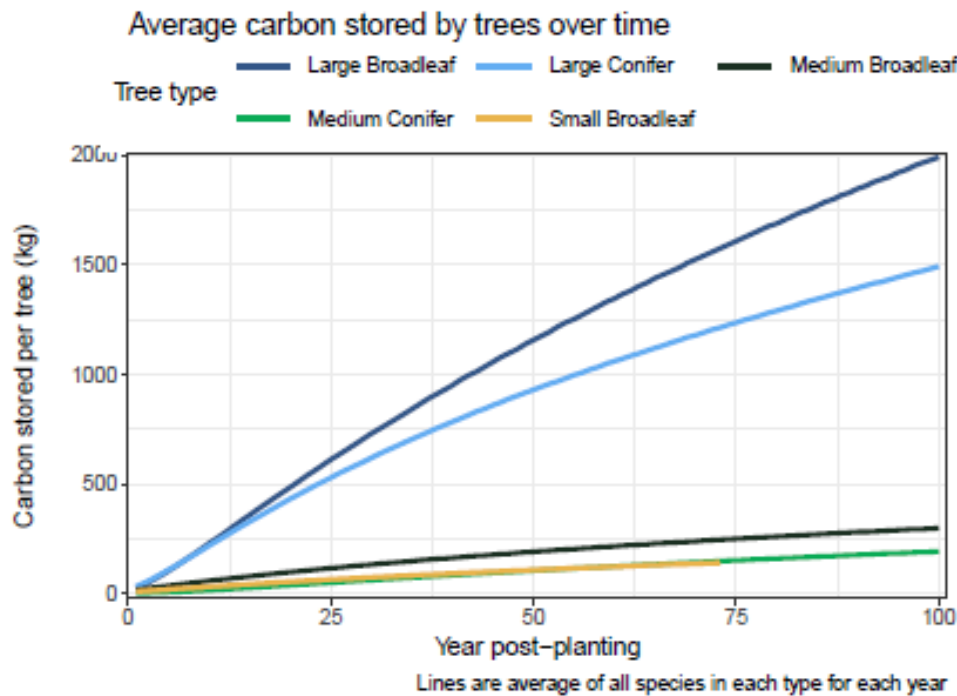


Figure 1. Average carbon stored by trees over time.

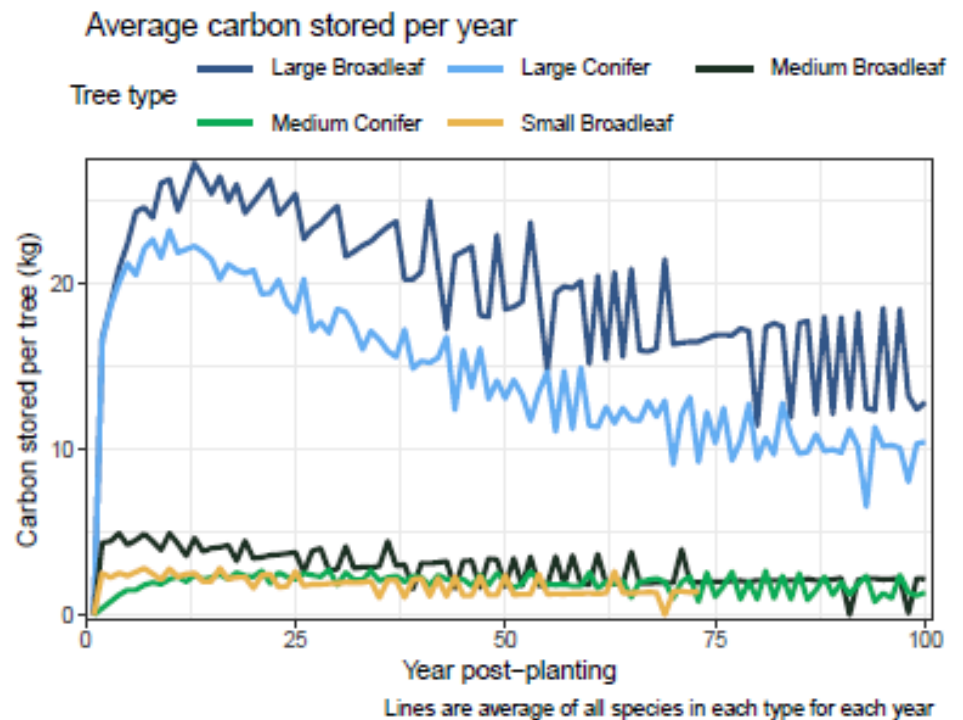
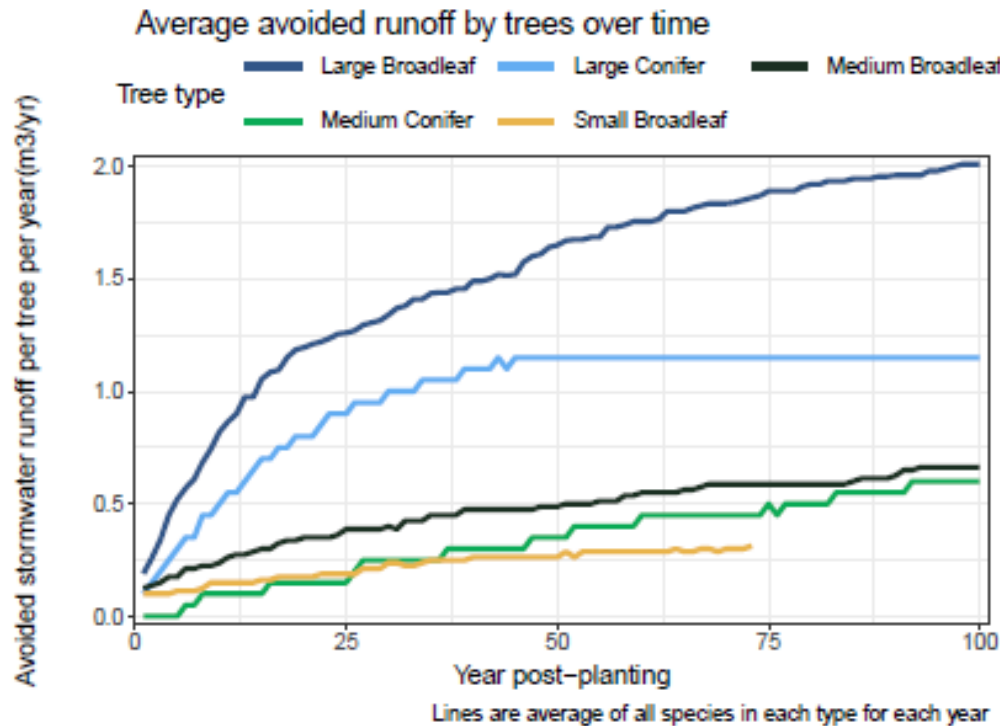
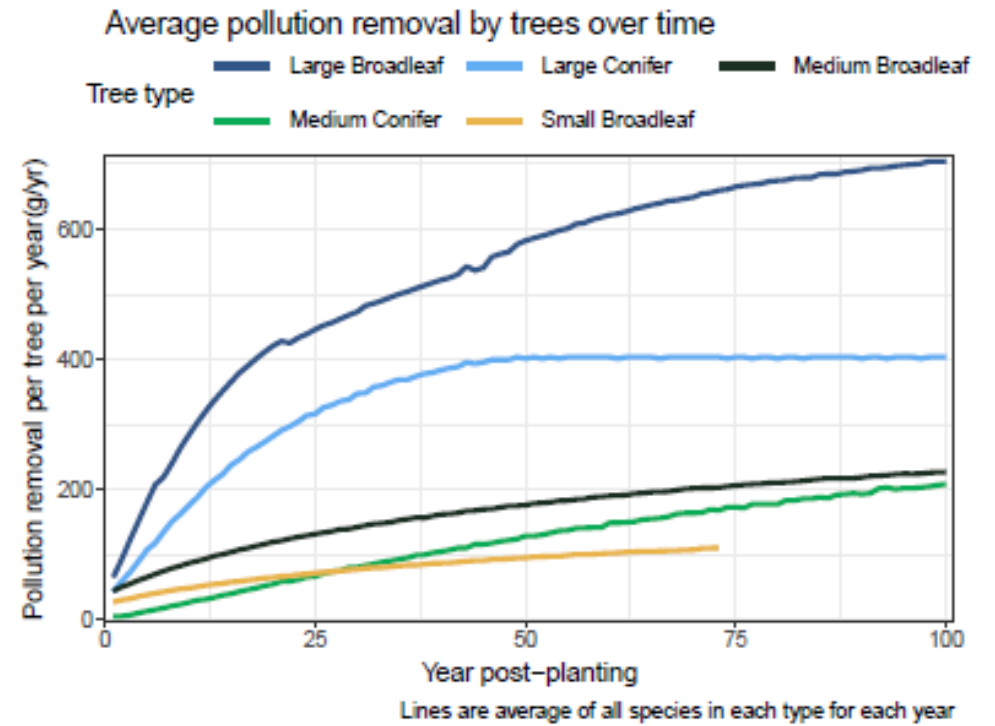


Figure 2. Average carbon stored per year.



Average amenity (CAVAT) by trees over time

Figure 3. Average avoided runoff by trees over time.



Ecosystem service delivery by trees over time

Figure 4. Average pollution removal by trees over time.

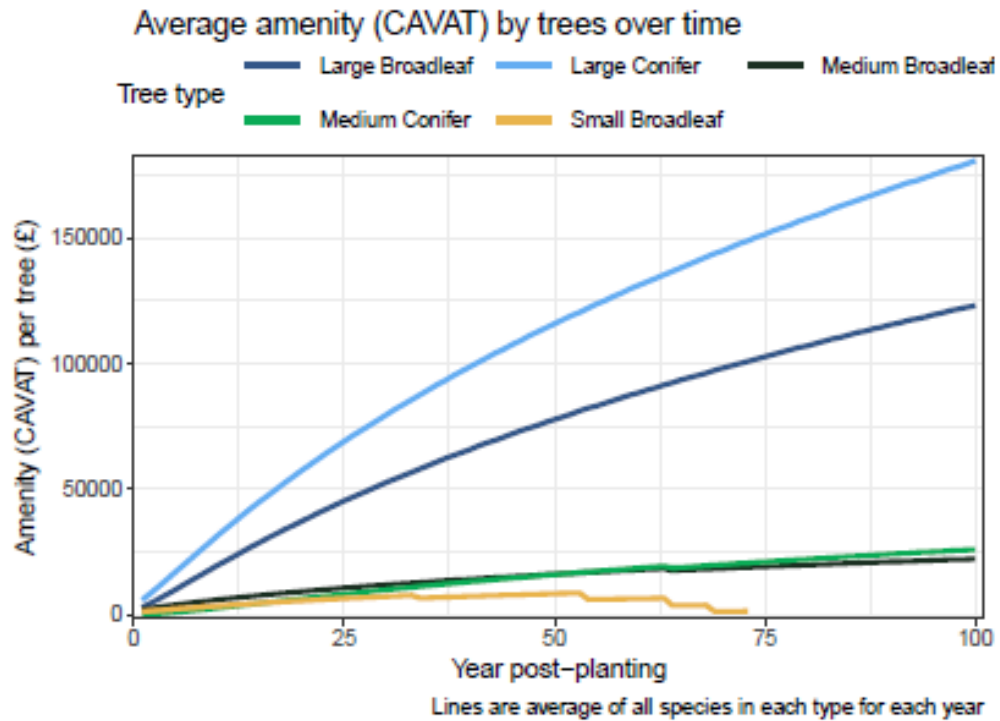


Figure 5. Average amenity (CAVAT) by trees over time.

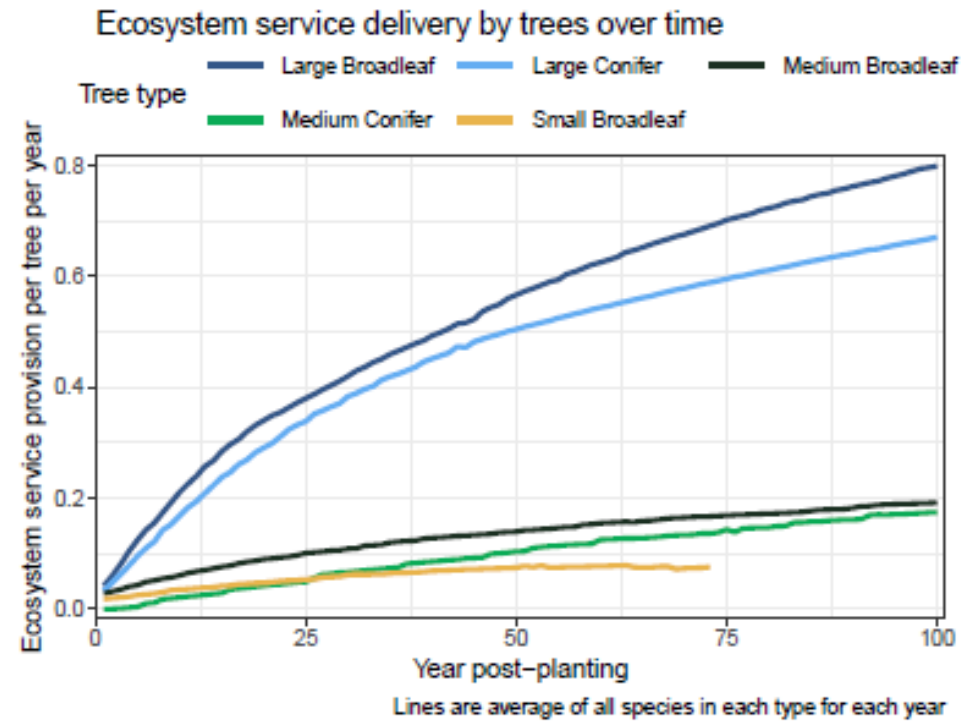


Figure 6. Ecosystem service delivery by trees over time.

### 3 Location

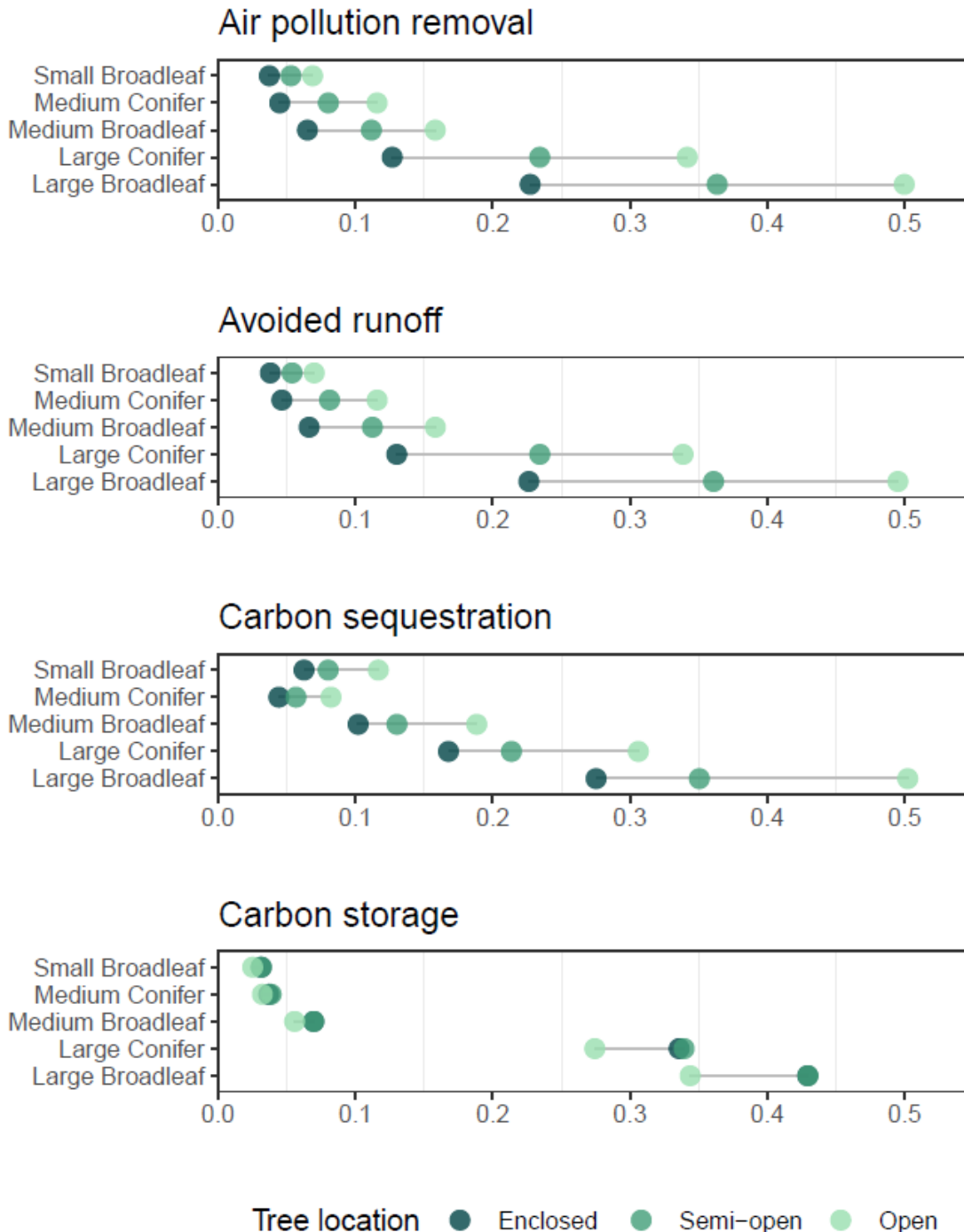


Figure 7. Average of ecosystem service provision by each tree type modelled in enclosed, semi-open, and open locations. Values are normalised between 0 and 1.

Figure 7 shows the effect of location (crown light exposure) on average provision of ecosystem services by each stature and leaf type group. All ecosystem services show a similar trend with the exception of carbon storage. In the carbon storage plot, trees in open locations are estimated in i-Tree Eco to have lower carbon storage than comparable trees in semi-open or enclosed locations. This is because the i-Tree Eco model assumes trees in open locations are street trees, and therefore subject to pruning, which reduces their biomass and consequently their total carbon storage (for more info see:

[https://www.itreetools.org/resources/manuals/ECOV6\\_ManualsGuides/ECOV6GuideDifferencesv5v6.pdf](https://www.itreetools.org/resources/manuals/ECOV6_ManualsGuides/ECOV6GuideDifferencesv5v6.pdf)).

This assumption may not always apply to urban trees in open locations, and we therefore may expect trees in open locations, such as lone trees in parks, to have equal carbon storage to similarly sized trees in other locations.

## 4 Total ecosystem service provision

Figure 8 shows total ecosystem service provision by the 30 species in this study, normalised between 0 and 1 across all species.

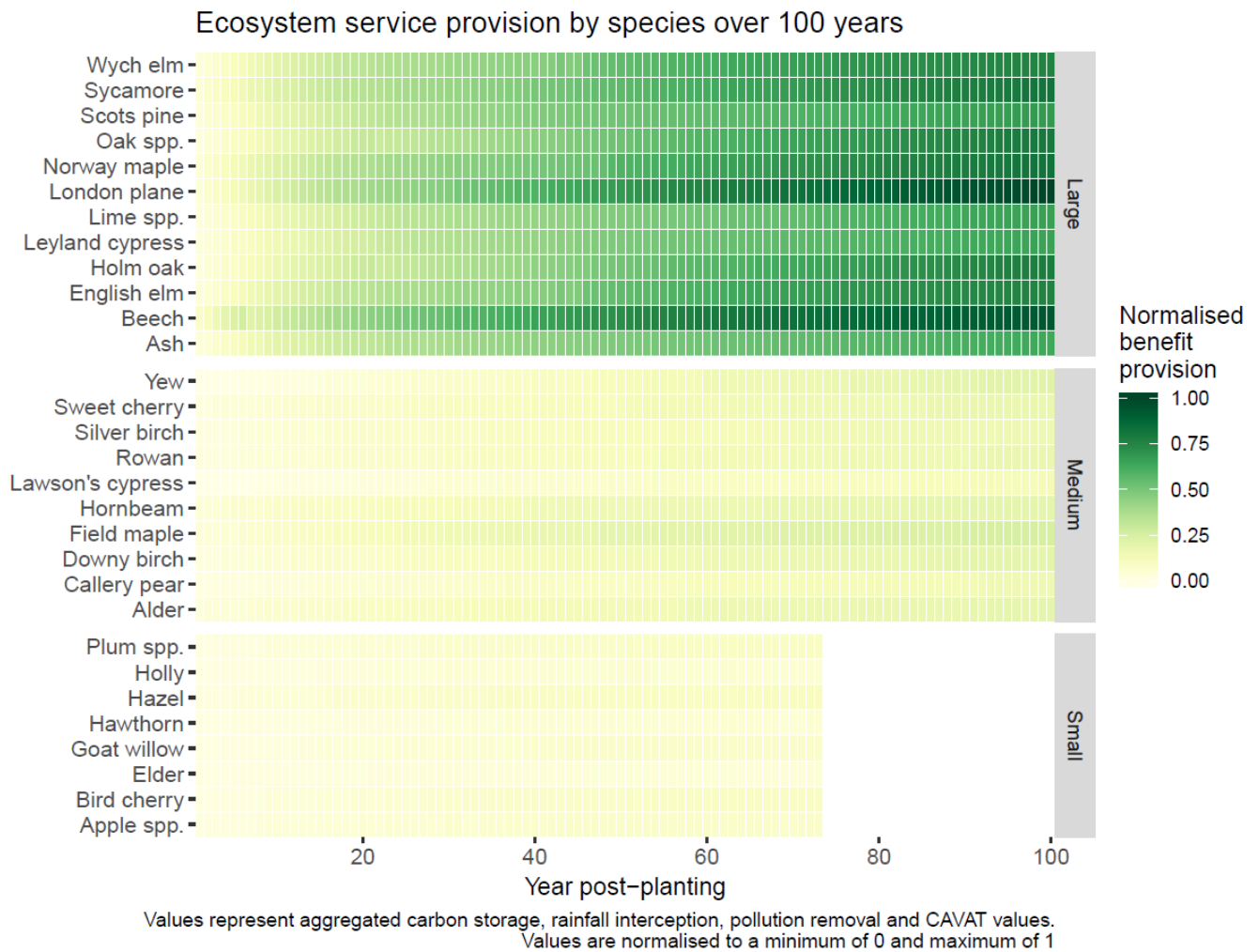


Figure 8. Ecosystem service provision over 100 years normalised across all species in the study. Lighter colours indicate less ecosystem service provision; darker colours indicate more ecosystem service provision.



## References

- Atkinson, M.D. and Atkinson, E. (2002). *Sambucus nigra* L.. *Journal of Ecology*, 90, 895-923.
- Buhler, O., Kristoffersen, P., and Larsen, S.U. (2007). Growth of street trees in Copenhagen with emphasis on the effect of different establishment concepts. *Arboriculture & Urban Forestry*, 33 (5), 330-337.
- Hindson, T. (2007). The growth rate of *Taxus Baccata*: an empirically generated growth curve. The Alan Mitchell Memorial Lecture. Accessed online at: <https://www.ancient-yew.org/userfiles/file/The%20Growth%20Rate%20of%20Taxus%20Baccata.pdf>
- Iszkuło, G., and Boratyński, A. (2011). Initial period of sexual maturity determines the greater growth rate of male over female in the dioecious tree *Juniperus communis* subsp. *communis*. *Acta Oecologica*, 37, 99-102.
- McPherson, E. G., van Doorn, N., and Peper, P. (2016). Urban Tree Database and Allometric Equations. Gen. Tech. Rep. PSW-GTR-253. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 86p. Information.
- Piggot, D. (1995). The radial growth-rate of Yews (*Taxus baccata*) at Hampton Court, Middlesex. *Garden History*, 23 (2), 249-252.
- Sjöman, H., Nielsen, A.B., Oprea, A. (2012). Trees for urban environments in northern parts of Central Europe –a dendroecological study in north-east Romania and Republic of Moldavia. *Urban Ecosystems*, 15, 267–281.
- Vaz Monteiro, M., Levanič, T., and Doick, K. J. (2017). Growth rates of common urban trees in five cities in Great Britain: a dendrochronological evaluation with an emphasis on the impact of climate. *Urban Forestry & Urban Greening*, 22, 11-23.

Willoughby, I., Stokes, V., Poole, J., White, J. E. J. and Hodge, S. J. (2007). The potential of 44 native and non-native tree species for woodland creation on a range of contrasting sites in lowland Britain. *Forestry*, 80, 531-553.

Wood, K. (2010). Growth rates of common tree species in Westminster, Colorado. Colorado State Forest Service, Fort Collins, Colorado.

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