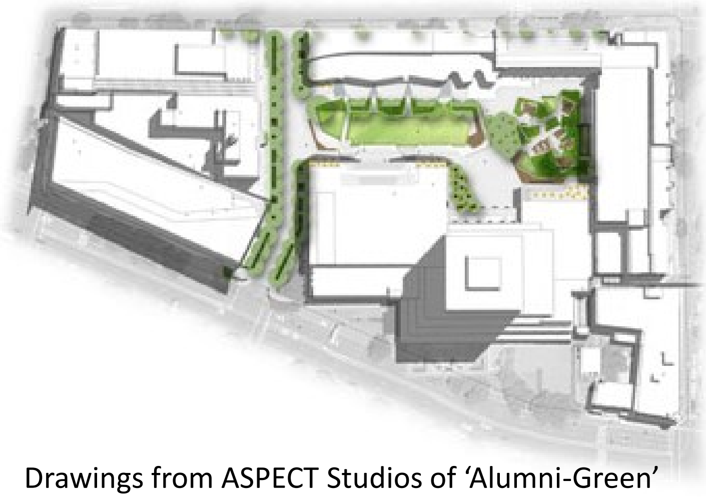
Establishment of Trees in Urban Environments

Dr Andrew Hirons

TDAG Seminar – October 2023

Drawings to reality?



Drawings from ASPECT Studios of 'Alumni-Green'
University of Technology, Sydney

The Multiplicity of the Problem

Progress??

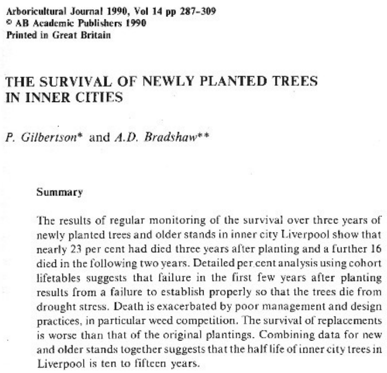
- Failure rates range between 10% - 80% within year 1 of planting
- Average young tree mortality rates in the UK are ~25%

Gilbertson and Bradshaw 1990

Johnston and Rushton 1999

Britt and Johnston 2008

- Urban tree life expectancy is ~ 19-28 years (Roman and Scatena (2011))



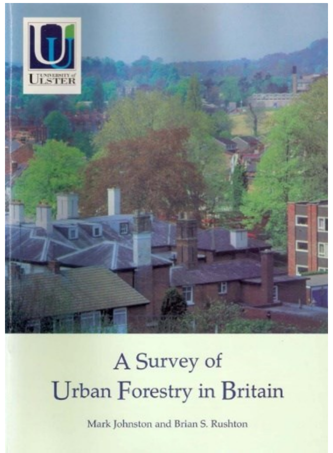
Arboricultural Journal 1990, Vol 14 pp 287–309
© AB Academic Publishers 1990
Printed in Great Britain

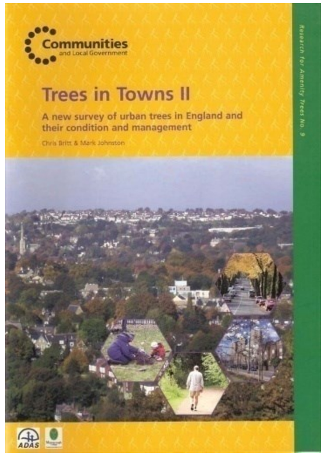
THE SURVIVAL OF NEWLY PLANTED TREES IN INNER CITIES

*P. Gilbertson** and *A.D. Bradshaw***

Summary

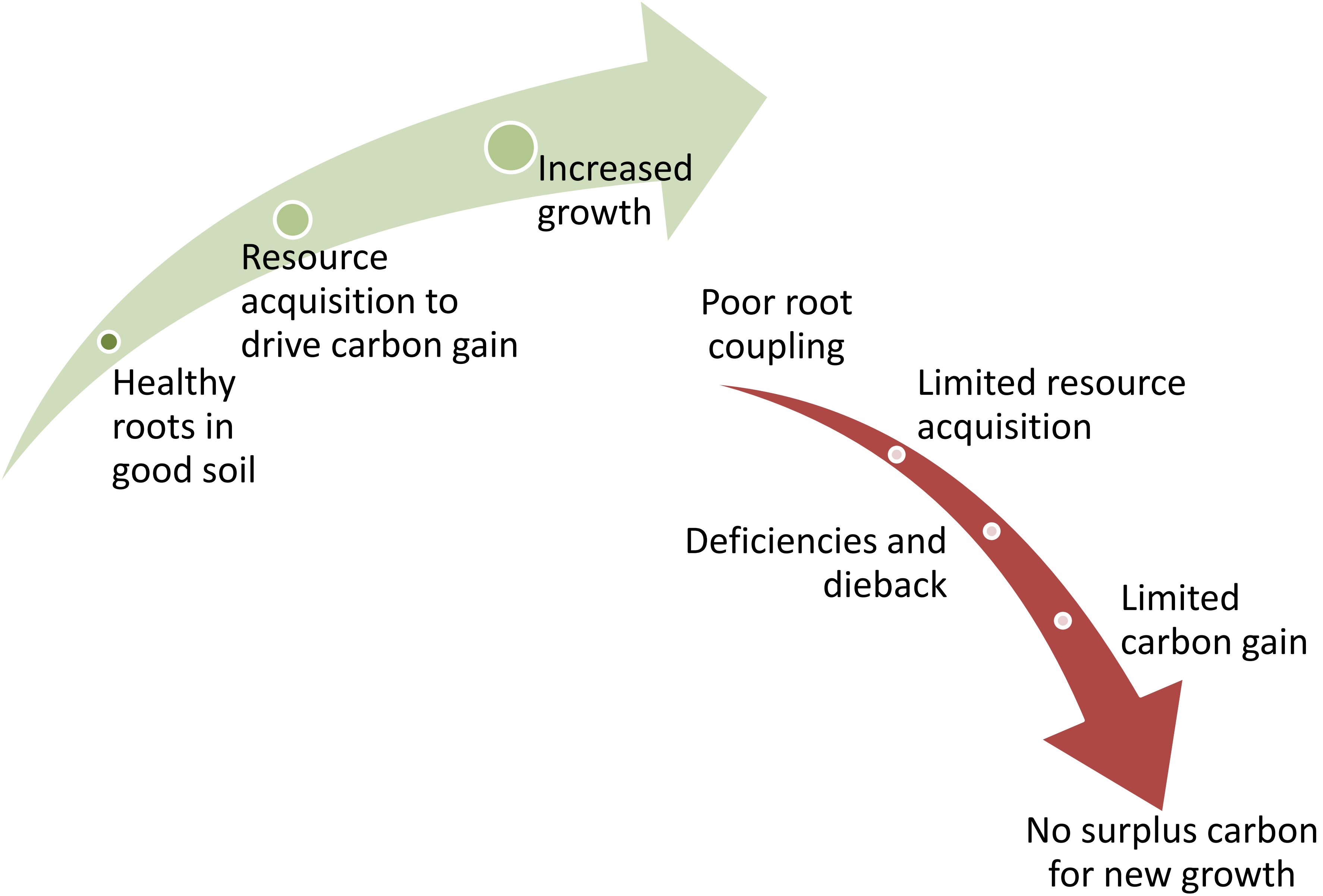
The results of regular monitoring of the survival over three years of newly planted trees and older stands in inner city Liverpool show that nearly 23 per cent had died three years after planting and a further 16 died in the following two years. Detailed per cent analysis using cohort lifetables suggests that failure in the first few years after planting results from a failure to establish properly so that the trees die from drought stress. Death is exacerbated by poor management and design practices, in particular weed competition. The survival of replacements is worse than that of the original plantings. Combining data for new and older stands together suggests that the half life of inner city trees in Liverpool is ten to fifteen years.





Hirons and Sjöman 2018

The momentum of establishment



Evidence for younger trees establishing faster

Influence of Tree Size on Transplant Establishment and Growth

W. Todd Watson[1]

ADDITIONAL INDEX WORDS. urban trees, urban forestry, arboriculture, tree planting, tree growth, root ball

SUMMARY. Studies have demonstrated that the size of transplanted trees has a measurable impact on establishment rates in the landscape. Larger trees require a longer period of time than smaller trees to produce a root system comparable in spatial distribution to similar sized non-transplanted trees. This lag in redevelopment of root system architecture results in reduced growth that increases with transplant size. Research has demonstrated that smaller transplanted trees become established more quickly and ultimately result in larger trees in the landscape in a few years. Additional studies dispute these findings. This paper provides a review of current research on the effect of tree size on transplant establishment.

Trees have been transplanted since ancient times. Egyptians transplanted trees as early as 2000 B.C., and early temple pictographs depict workers transporting frankincense trees (*Boswellia* sp.) in containers. Records reveal that the Egyptians transported large trees by ships from faraway lands to be transplanted in Egypt (Campana, 1999). As mechanization and knowledge of arboriculture have increased, so have the sizes of trees that have been planted. Tree transplanting technology has now reached a level where any size tree can be excavated and successfully transplanted to a new location (Harris et al., 2004; Watson and Himelick, 1997).

Transplanting procedures and success rates have been largely based on anecdotal evidence (Gilman, 1990; Struve et al., 2000; Watson, 1985). Experimental techniques have recently begun to be applied to identify and measure stresses associated with transplanting trees. Recent studies have suggested that transplanting large trees may not necessarily result in a larger tree over time. Some research reveals that smaller sized transplants become established more quickly and may eventually outgrow larger transplants due to a shortened establishment period (Lauderdale et al., 1995; Watson, 1985). Other studies do not support these findings and propose that several factors should be considered when comparing establishment and growth rates of small and large transplanted trees (Gilman et al., 1998; Struve et al., 2000).

The goal of this paper is to review recently published research on transplanted trees in relation to the size of nursery stock used. The findings from these studies will be compared to provide a better understanding of how various factors affect establishment and post-transplant growth rates of small and large trees.

Post-transplant stresses

According to Struve et al. (2000), "transplanting stress is a temporary condition of distress resulting from injuries, depletion, and impaired function." It is generally assumed that "transplant shock" is largely due to stresses resulting from removal of a substantial portion of the transplanted trees' root systems, which creates a root-shoot imbalance (Watson, 1985). However, several additional stress factors can affect post-transplant survivability and recovery rates of trees from transplant shock. Gilman (1990) and others (Bevington and Castle, 1985; Fare et al., 1985) proposed that establishment rates are dependent on such factors as tree species, environmental conditions, physiological status of tree transplants, time of year, cultural practices, and type of root system. Struve et al. (2000) further proposed that in addition to these factors, provenance, root ball : canopy volume ratio, and relative root ball to backfill volume may also have confounding effects on establishment and growth rates of various sizes of transplanted trees.

When using ANSI Z60.1 standards (American Association of Nurseryman, 1996), the size of the root ball is always proportional to the size of the tree (Himelick, 1981). Only 2% to 5% of the soil rooting volume is harvested when assuming that the root system is in the upper 45.7 cm (18 inches) of soil and extends out from the truck up to three times the diameter of the dripline of the tree (Gilman, 1988a; Watson and Himelick, 1982a). When measuring root length harvested with some species of field-grown trees, the amount of roots harvested within the root ball range from 5% to 8% (Gilman, 1988b; Watson and Sydnor, 1987). If the weights of roots are considered, up to 84% of root weight is harvested in the root ball of field-dug trees due to the concentration of larger roots near the trunk (Gilman and Beeson, 1996). At least one study demonstrated that 55% of the total surface area of roots is retained within the excavated root ball (Harris and Gilman, 1993).

Post-transplant establishment rates

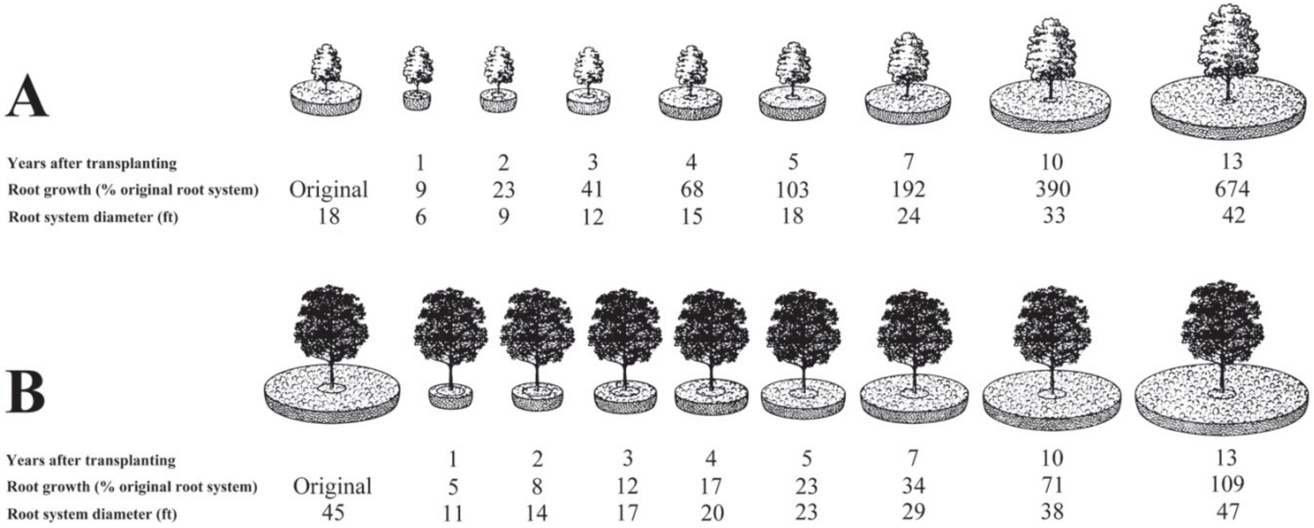
Due to this loss of root system, transplanted trees experience a phase after planting in which growth is significantly reduced (Fig. 1). This lag in growth is due in large part to a reduction in the acquisition and assimilation of water and essential minerals and an expenditure of stored carbohydrates to regenerate new roots (Gilman et al., 1998; Lauderdale et al., 1995; Watson, 1985). Consequently, this lag phase is more pronounced during the early stages of the establishment period, but growth rate increases as the root system approaches its original size (Gillman and Beeson, 1996; Watson, 1987). In order to become fully established in the landscape, transplanted trees must generate a new root system so that shoot growth is comparable to a non-transplanted tree (Watson and Himelick, 1997). To achieve a pre-transplant root system, roots typically have to grow to a distance equal to three times the diameter of the canopy width (Gilman, 1988b; Watson and Himelick, 1982a).

The length of time for trees to become fully established depends on the rate of root elongation and the extent of original root spread (Watson, 1992). Depending on species and growing conditions, when roots are cut, it takes 6 to 49 d for adventitious roots to form (Arnold and Struve, 1989; Shoemake et. al., 2004; Struve and Rhodus, 1988). Root elongation rates are similar for small and large trees (Watson, 1985; Watson and Himelick, 1982b). Elongation rates

Department of Forest Science, Texas A&M University, College Station, TX 77843-2135

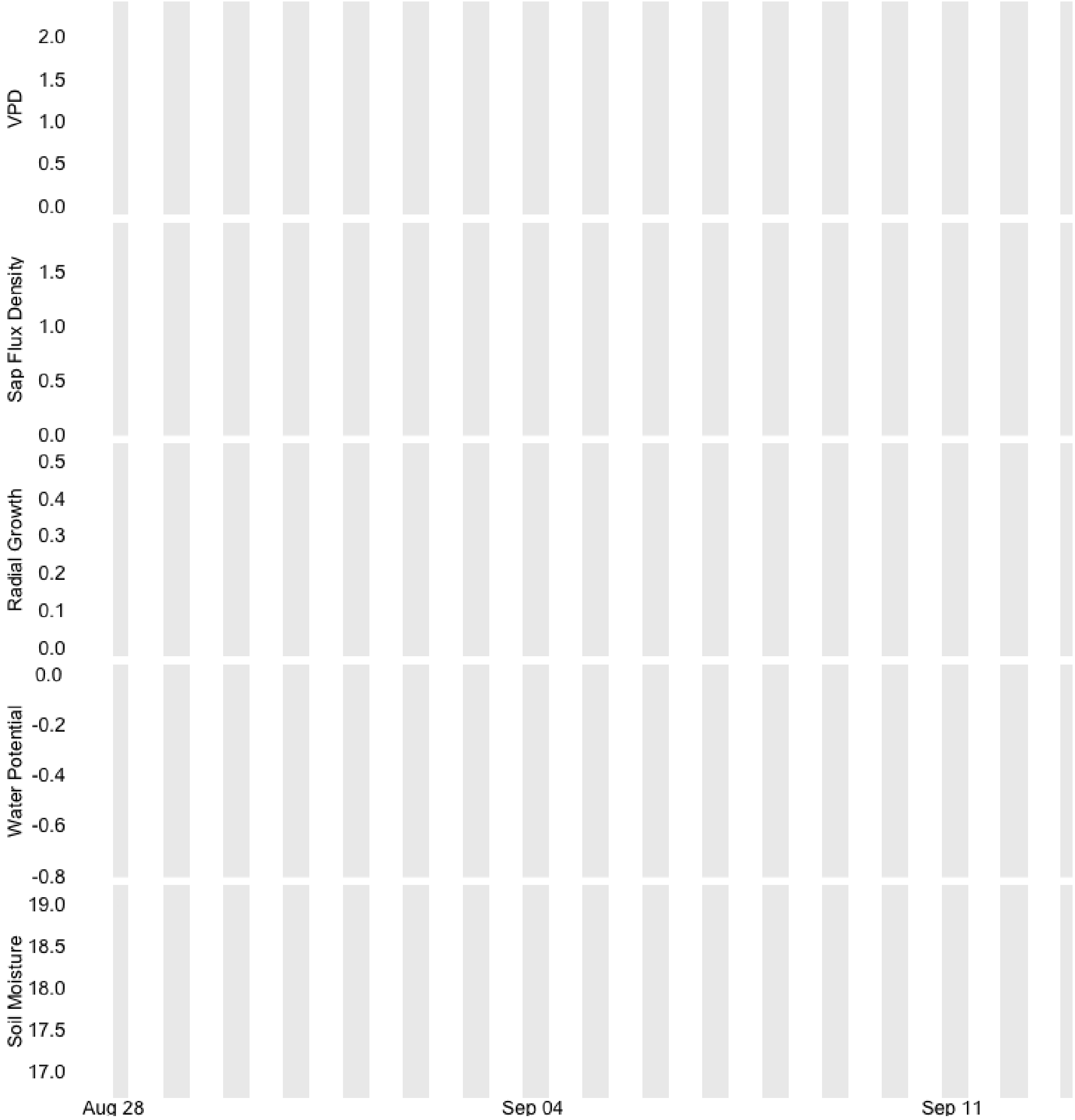
[1]To whom reprint requests should be addressed. E-mail address: t-watson@tamu.edu

- Much evidence exists to suggest that young trees establish more rapidly than older trees.



Trees live in dynamic environments

Ulmus 'New Horizon'

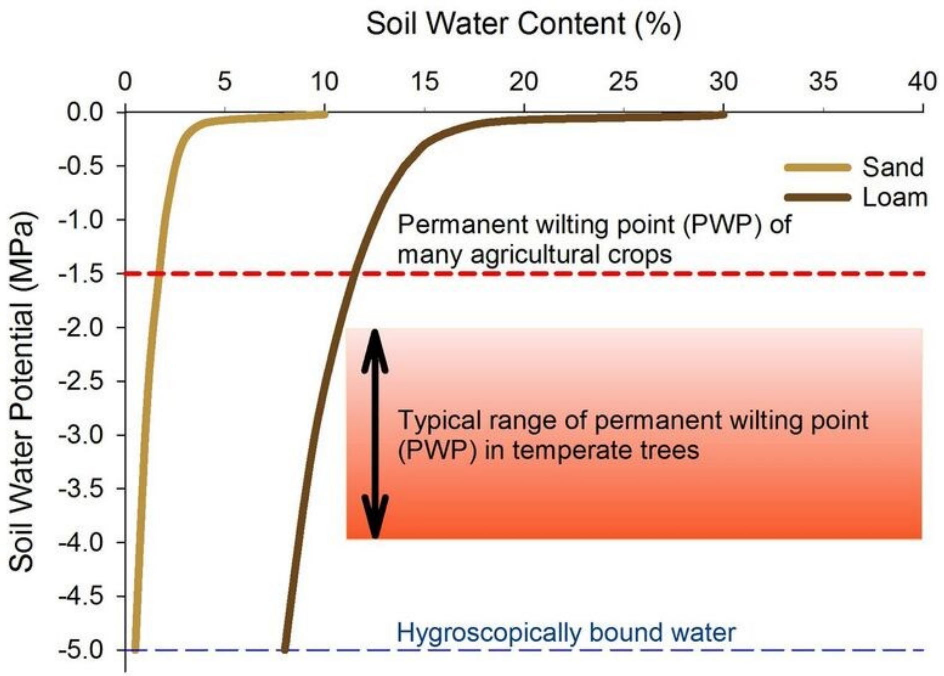


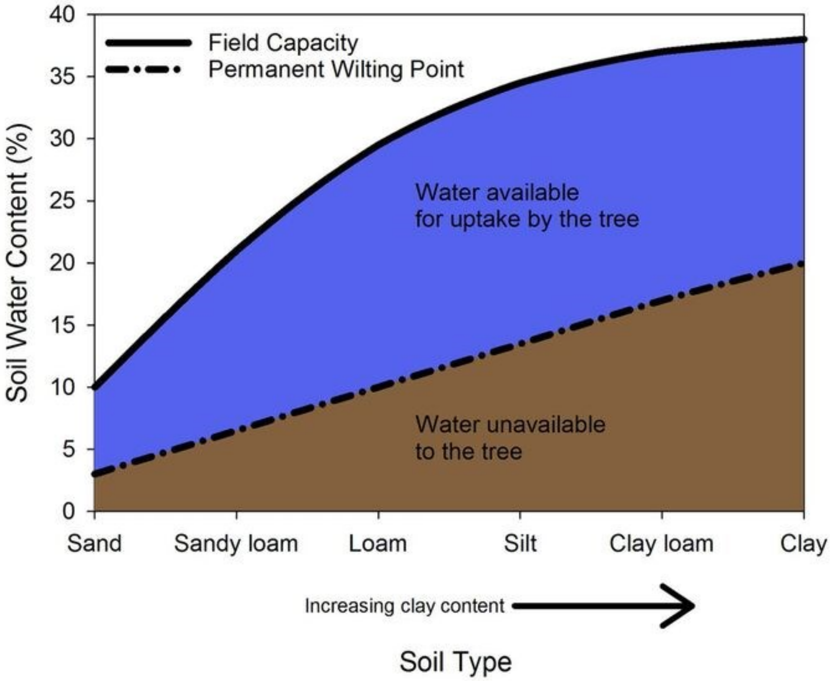
TREE SIZE : SOIL VOLUME

How much soil does a tree need?

- Greatest contribution soil makes is the provision of water.
- Volume of water required by the tree…
  - Leaf area (but also leaf microclimate)
  - Atmospheric demand (vapour pressure deficit (VPD))
- Nutrition is important in the medium to longer term.

Soil water release

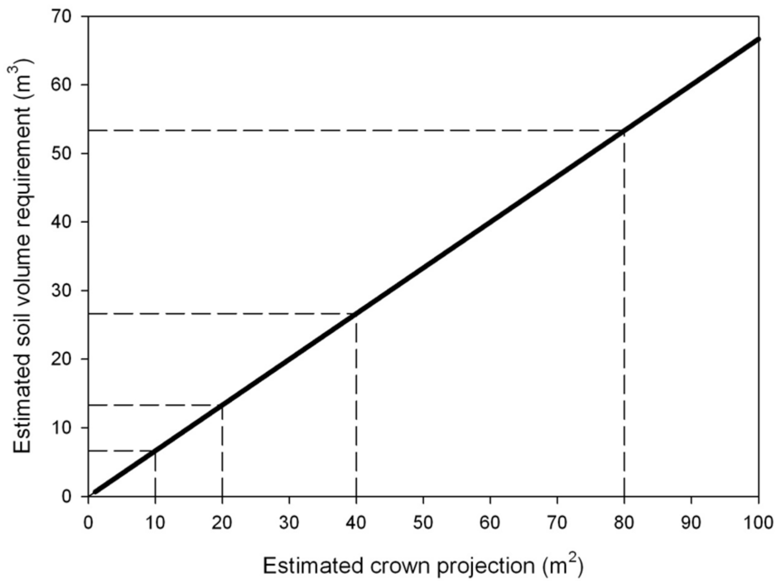


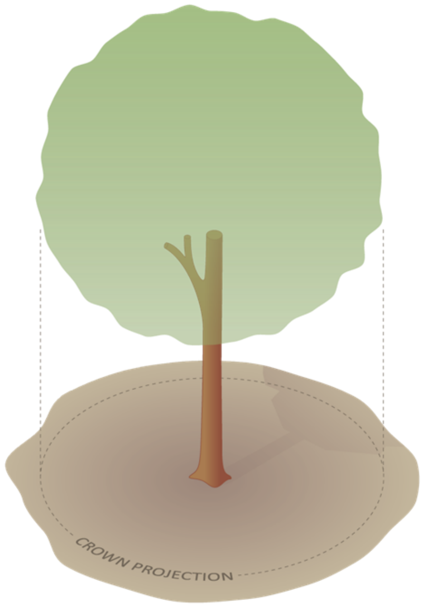


How much soil do we need?

Percentage of available soil water	Soil volume (m^3) required to deliver a given number of litres day^{-1} to a tree (maximum soil water recharge period = 14 days)					
	50 l	100 l	200 l	300 l	400 l	500 l
10	7.0	14.0	28.0	42.0	56.0	70.0
11	6.4	12.7	25.5	38.2	50.9	63.6
12	5.8	11.7	23.3	35.0	46.7	58.3
13	5.4	10.8	21.5	32.3	43.1	53.8
14	5.0	10.0	20.0	30.0	40.0	50.0
15	4.7	9.3	18.7	28.0	37.3	46.7
16	4.4	8.8	17.5	26.3	35.0	43.8
17	4.1	8.2	16.5	24.7	32.9	41.2
18	3.9	7.8	15.6	23.3	31.1	38.9
19	3.7	7.4	14.7	22.1	29.5	36.8
20	3.5	7.0	14.0	21.0	28.0	35.0

Calculating Soil Volume Requirements





0.6 m^3 soil for each 1 m^2 of crown projection

Urban Plaza Experiment

Photos: E. Thomas Smiley

Trial research

BARTLETT SCIENCE
SCIENTIFIC TREE CARE SINCE 1907

GreenBlue URBAN
Establishing the future urban landscape


Sand based SS


Gravel based SS


StrataCell

Root Environment Matters!

Photo: Johan Ostberg

Effect of rooting conditions on the growth and cooling ability of Pyrus calleryana*

- A total of 49 6-year old *Pyrus calleryana* trees were selected growing on 5 different streets near the Victoria Park and Rusholme area in Manchester.

Pavements

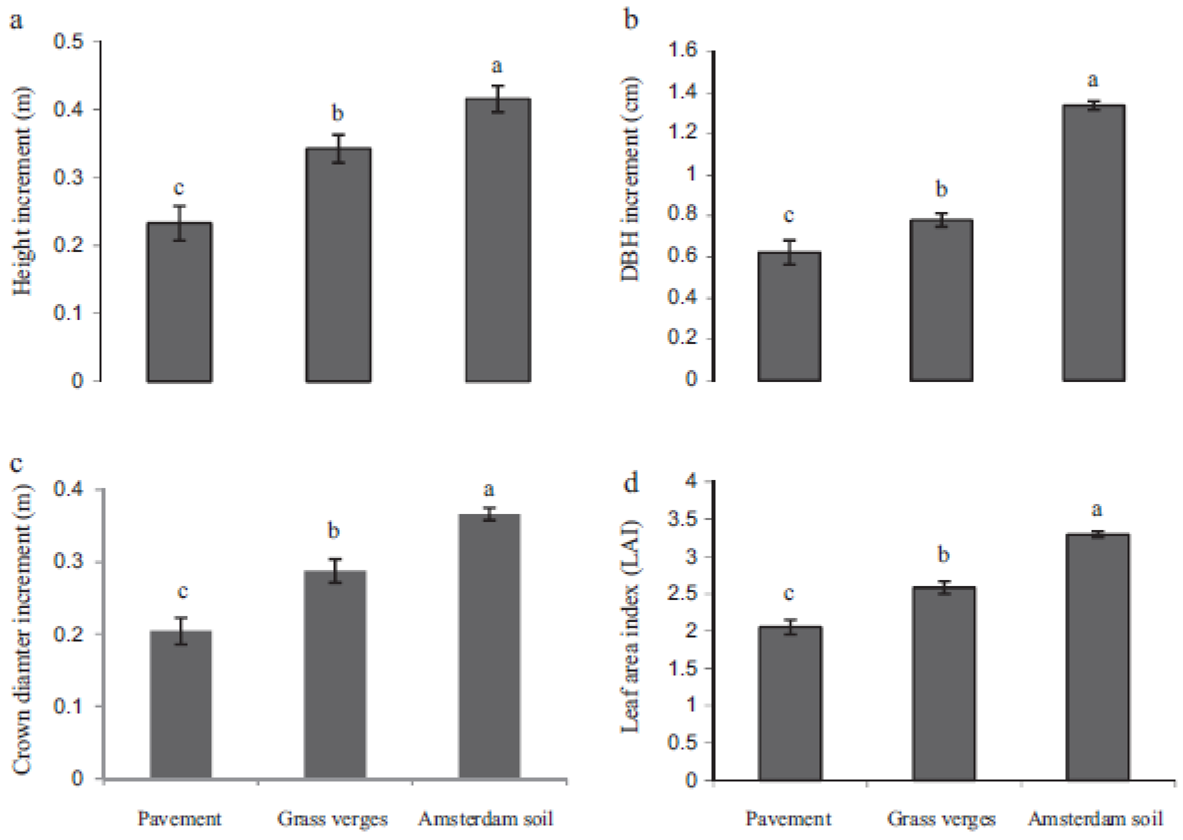
Grass verges

Amsterdam soil

Photos courtesy of Asrafur Rahman

*Rahman et al. 2012 Urban Forestry and Urban Greening (10) 185-192

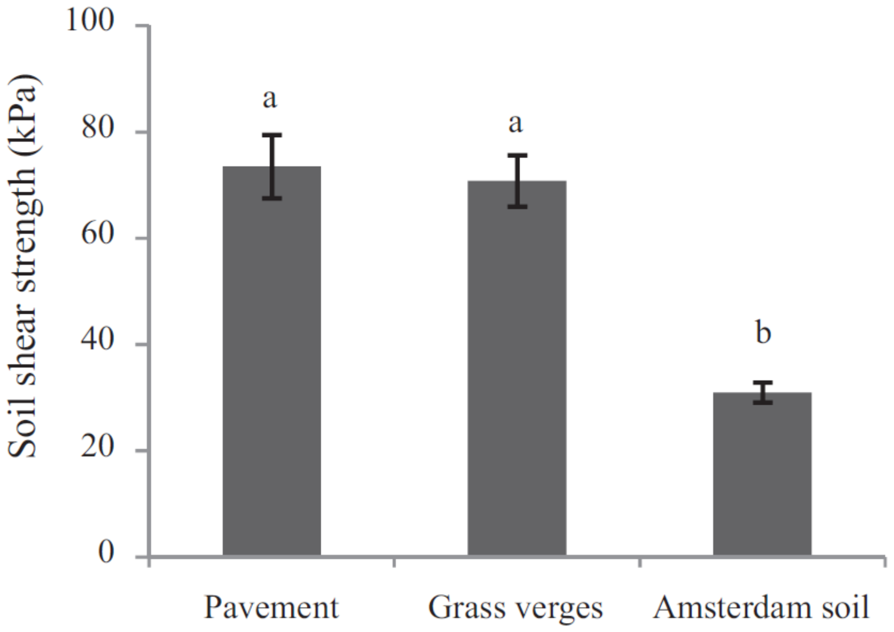
Trees in Amsterdam soil had faster growth in height, DBH and crown diameter and a higher LAI



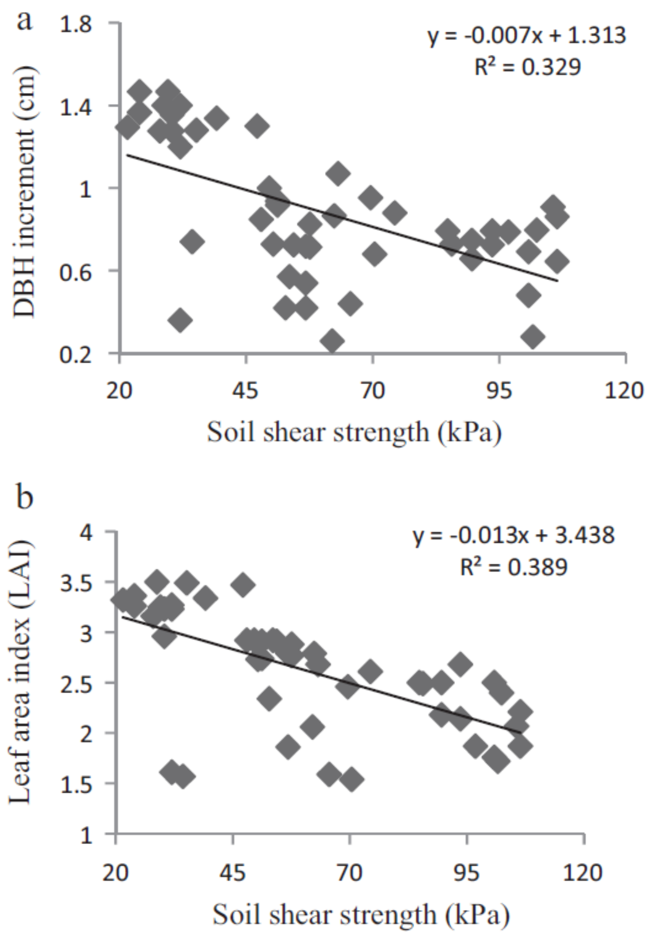
Differences in growth and morphology of P. calleryana grown on three different planting regimes. Annual growth increments (2004–10) in (a) height, (b) DBH and (c) crown diameter and (d) LAI of the crown in May 2010. Graphs show means ± standard error (n = 15 for paved streets, 21 for grass verges and 13 for Amsterdam soil).

Rahman et al. 2012 Urban Forestry and Urban Greening (10) 185-192

Amsterdam soil reduces the impact of compaction



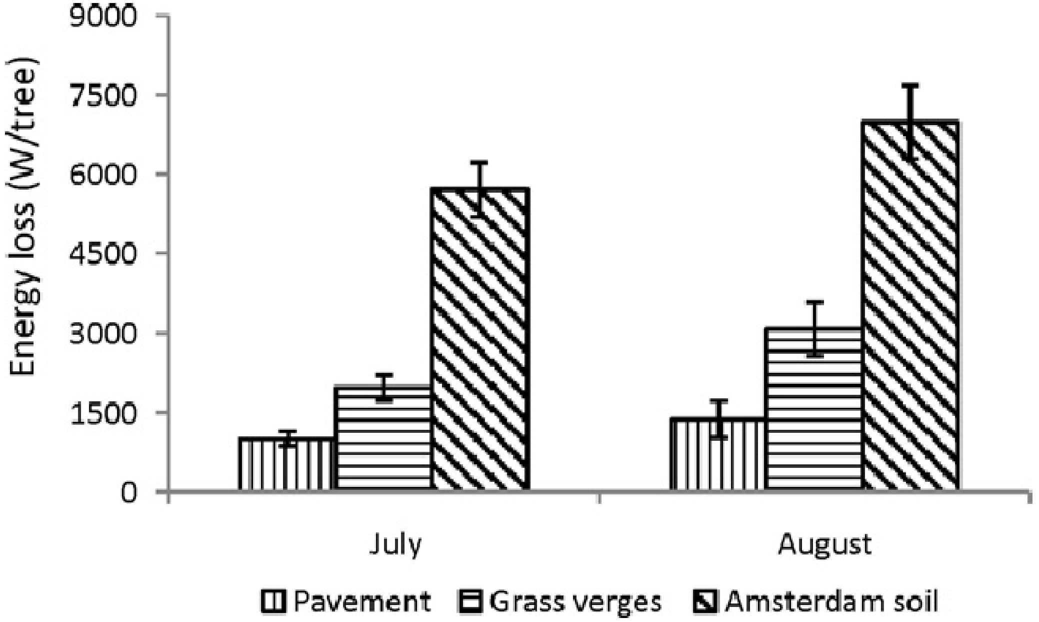
Shear strength of soil around P. calleryana trees grown in different planting regimes. Graphs show means ± standard error (n = 15 for paved streets, 21 for grass verges and 13 for Amsterdam soil).



Effect of soil shear strength on the growth and morphology of P. calleryana (a) diameter growth and (b) LAI increase.

Rahman et al. 2012 Urban Forestry and Urban Greening (10) 185-192

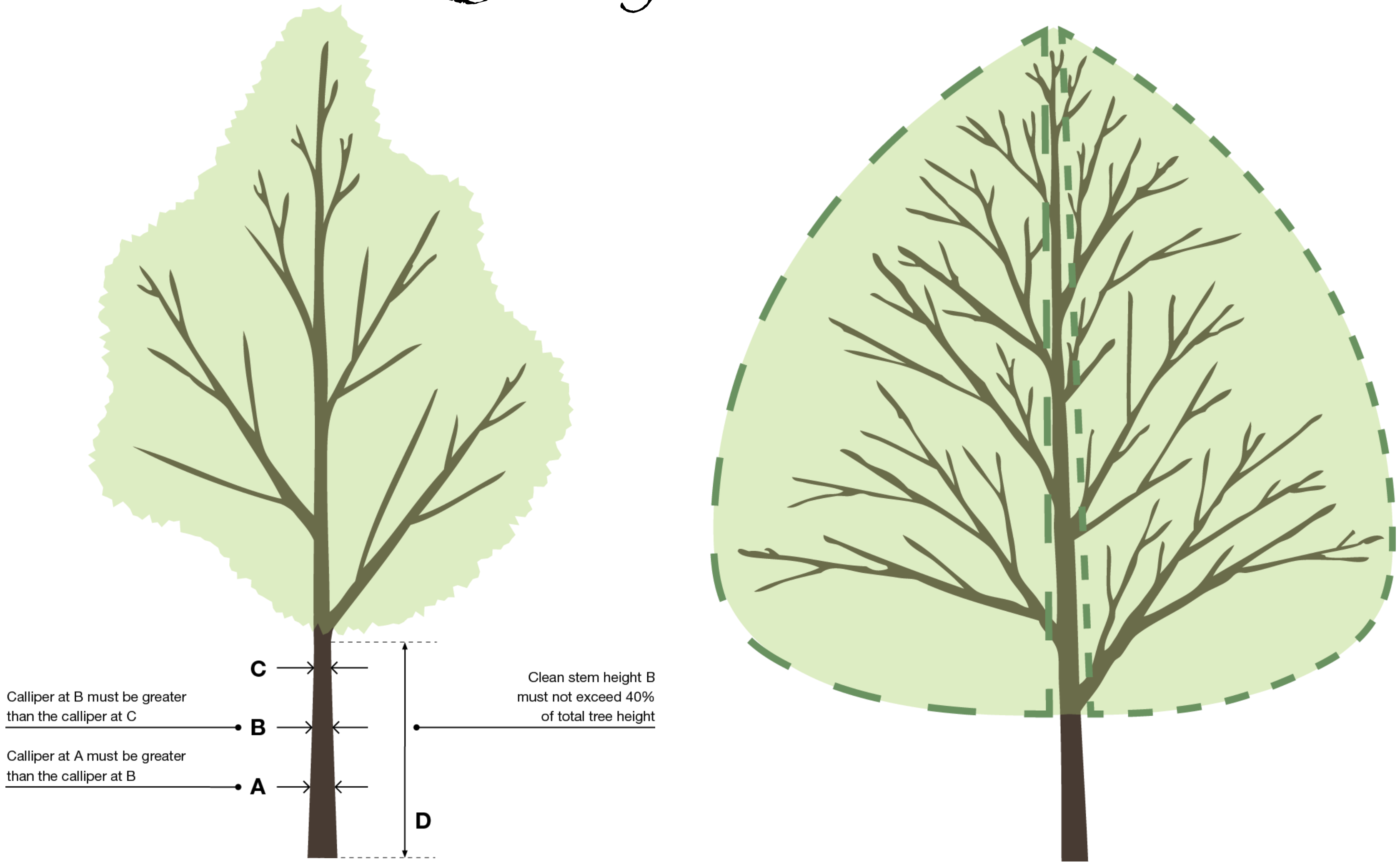
Evapotranspirational Cooling of Pyrus calleryana



Evapotranspirational cooling calculated for P. calleryana trees growing in three different planting regimes (n = 15 for paved streets, 21 for grass verges and 13 for Amsterdam soil).

Rahman et al. 2012 Urban Forestry and Urban Greening (10) 185-192

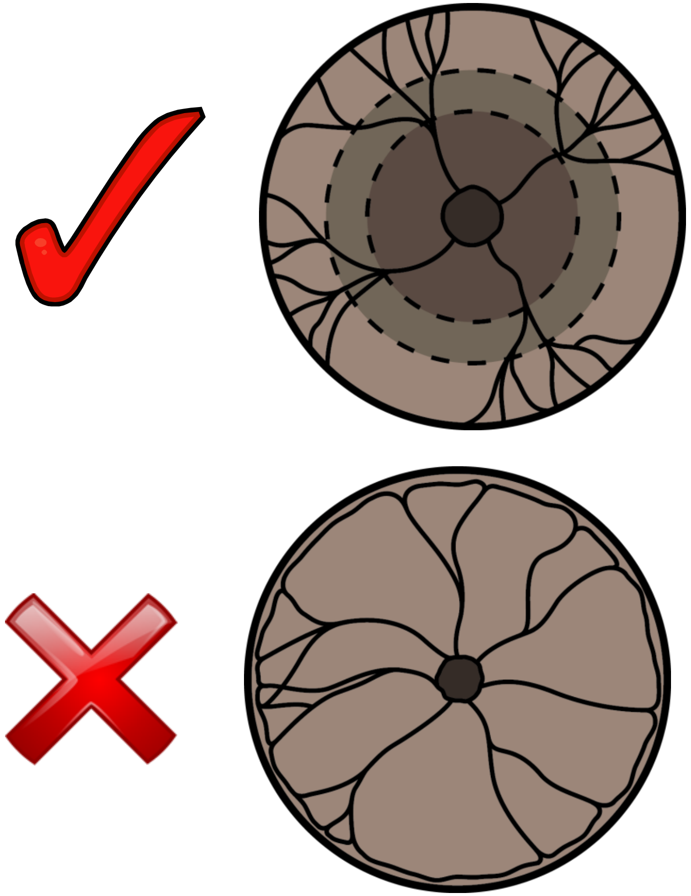
Plant Quality – Above Ground

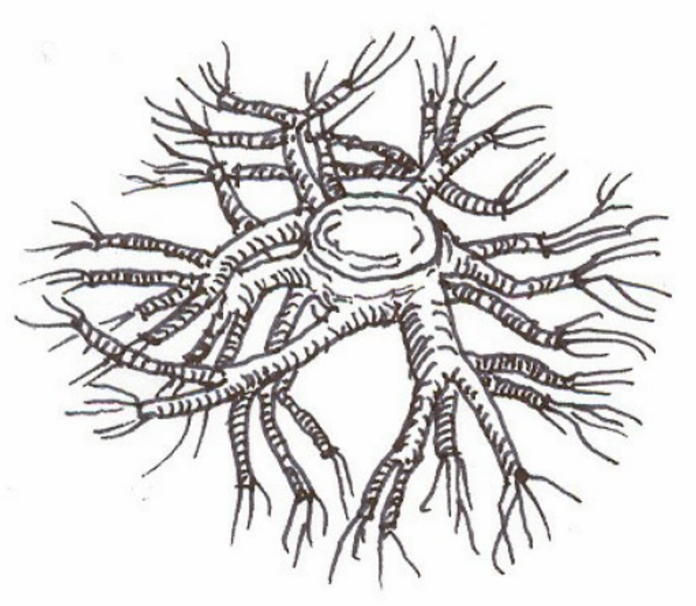


- Stem taper and crown symmetry

Redrawn from: Clark 2003

Plant Quality – Below Ground

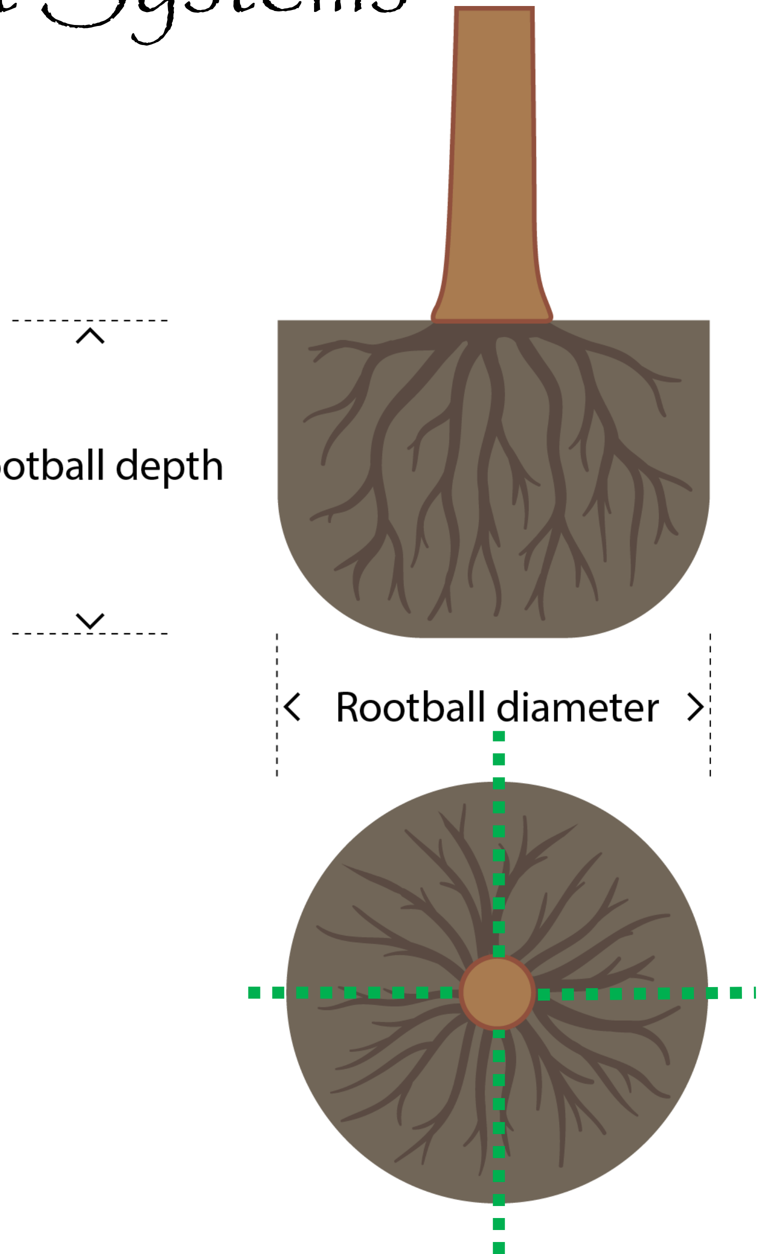




Hvass (2008)

Specifying Root Systems

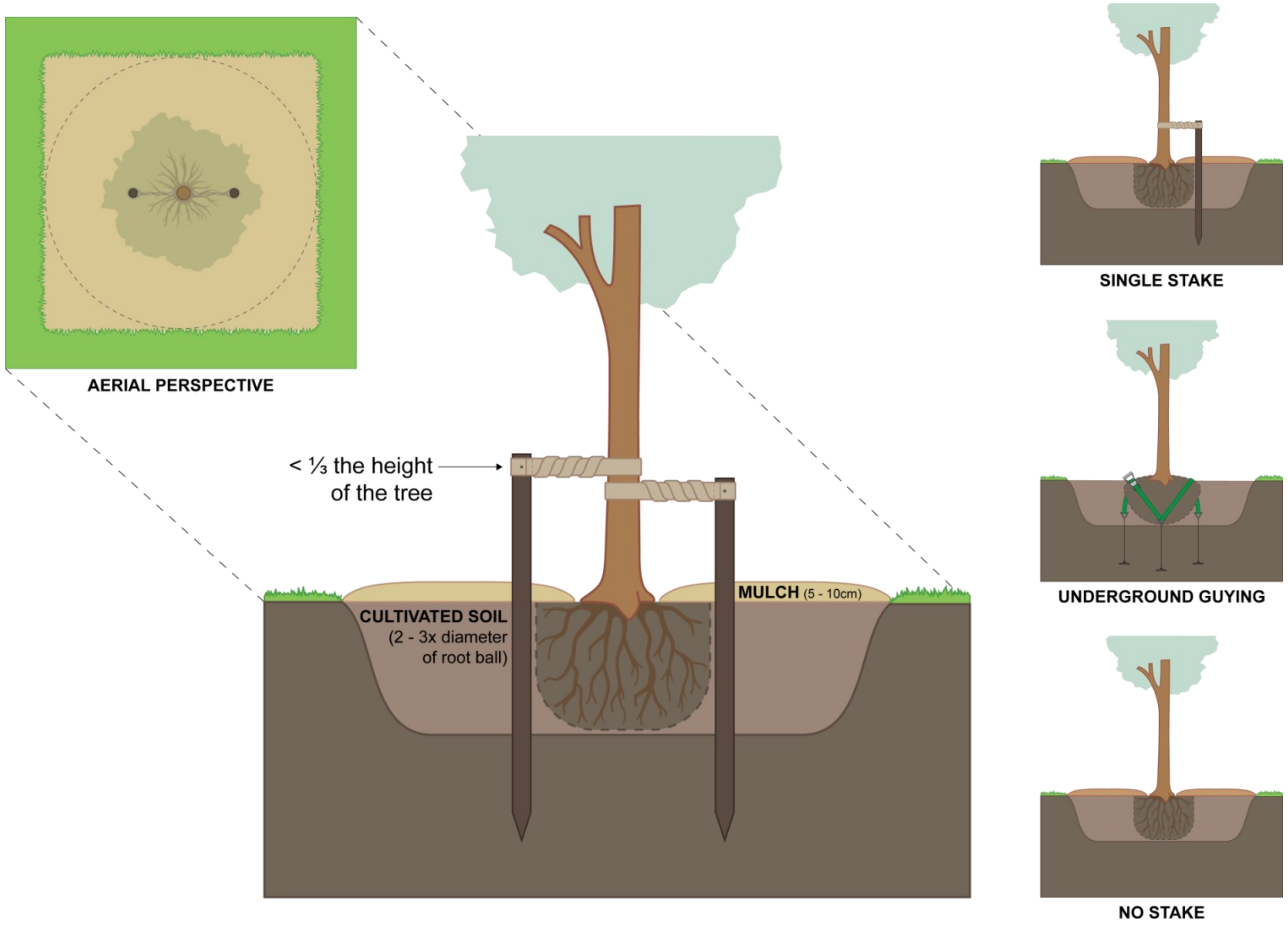
- Rootball diameter should be greater than rootball depth
- Root development should be apparent in each quarter of the rootball



Criteria for specification

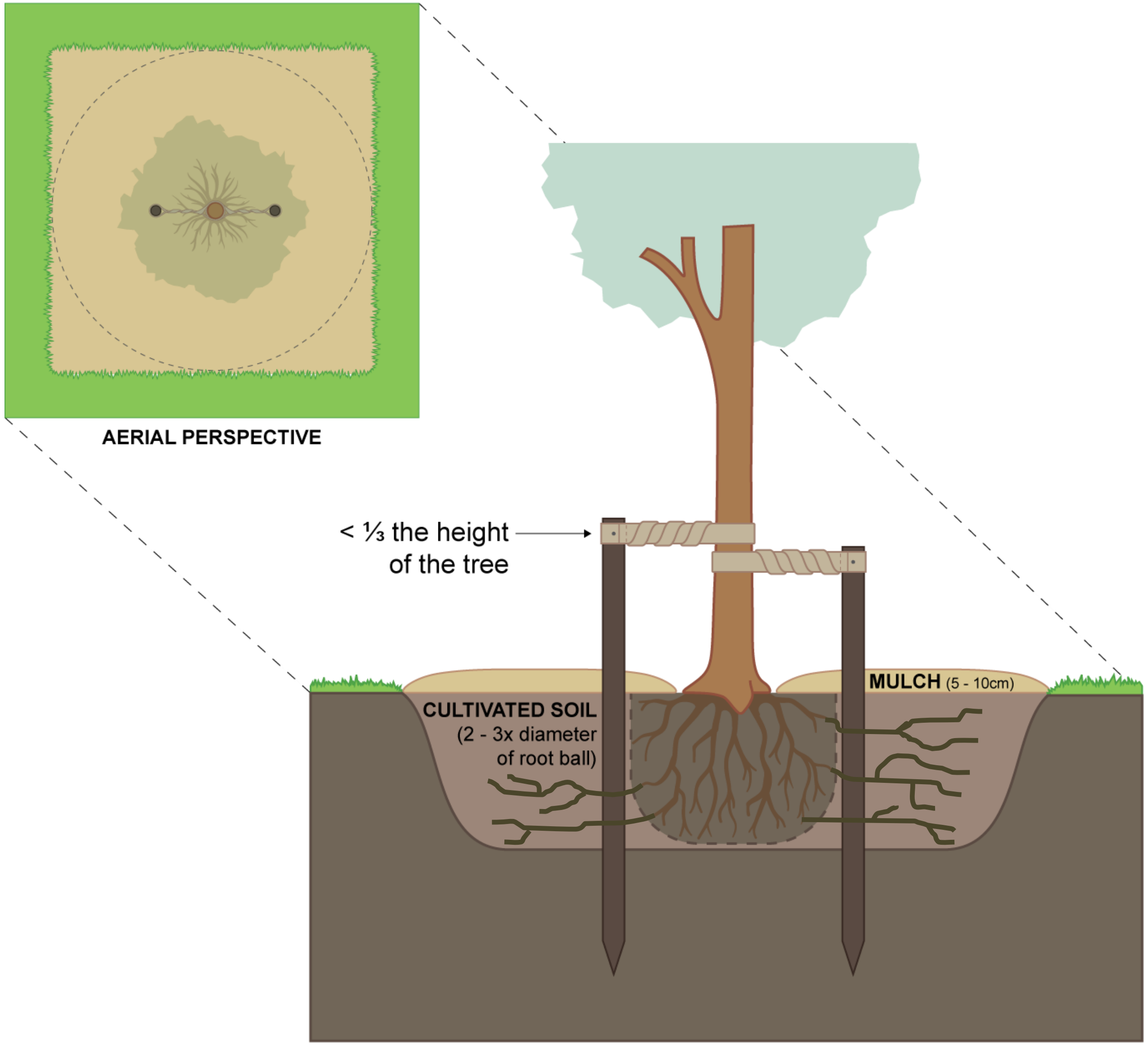
Specification elements	Specification criteria
Tree characteristics before planting	• Specimen true to species or variety type • Graft compatibility (if appropriate) • Healthy with good vitality • Free from pests, disease or abiotic stress • Free from injury • Self-supporting with good stem taper • Stem-branch transition height • Sound branch attachment and structure • Good pruning wound occlusion • Canopy symmetry • High rootball occupancy • Diversity in rooting direction • Good root division • Extensive fibrous root system • Free from root defects (e.g. circling roots) • Free pests, disease or abiotic stress

Tree Planting Practice



Hirons and Percival 2012

Root-Soil Coupling



Specification elements	Specification criteria
Planting pit and rootzone	• Planting pit 2-3 times the diameter of the rootball • Imported soil is of defined standard (e.g. BS 3882) • Low soil bulk density (1.2 g cm^{-3}) maintained in planting pit and rootzone • Potential rooting (soil) volume adequate for mature tree of species planted
Planting practice	• Hessian, wire baskets and other containers removed from rootball and correctly disposed of • Tree planted at stem-root transition • Tree upright and supported (where necessary) using above or below ground techniques
Formative pruning	• Damaged branches removed using natural target pruning methodology • Rubbing and crossing branches removed • Sub-ordination of competing stems
Tree aftercare	• Mulch to depth of between 5 and 10cm and to defined width. Stem to remain exposed and not buried by mulch • Mulch replenishment schedule defined • Irrigation schedule based on local soil variables (preferably soil matric potential) • Tree protection and support to have defined timescale for evaluation and/or removal

Tree Species Selection for Green Infrastructure

Issue 1.3/2019

A Guide for Specifiers

Written by:
Dr Andrew Hirons and Dr Henrik Sjöman

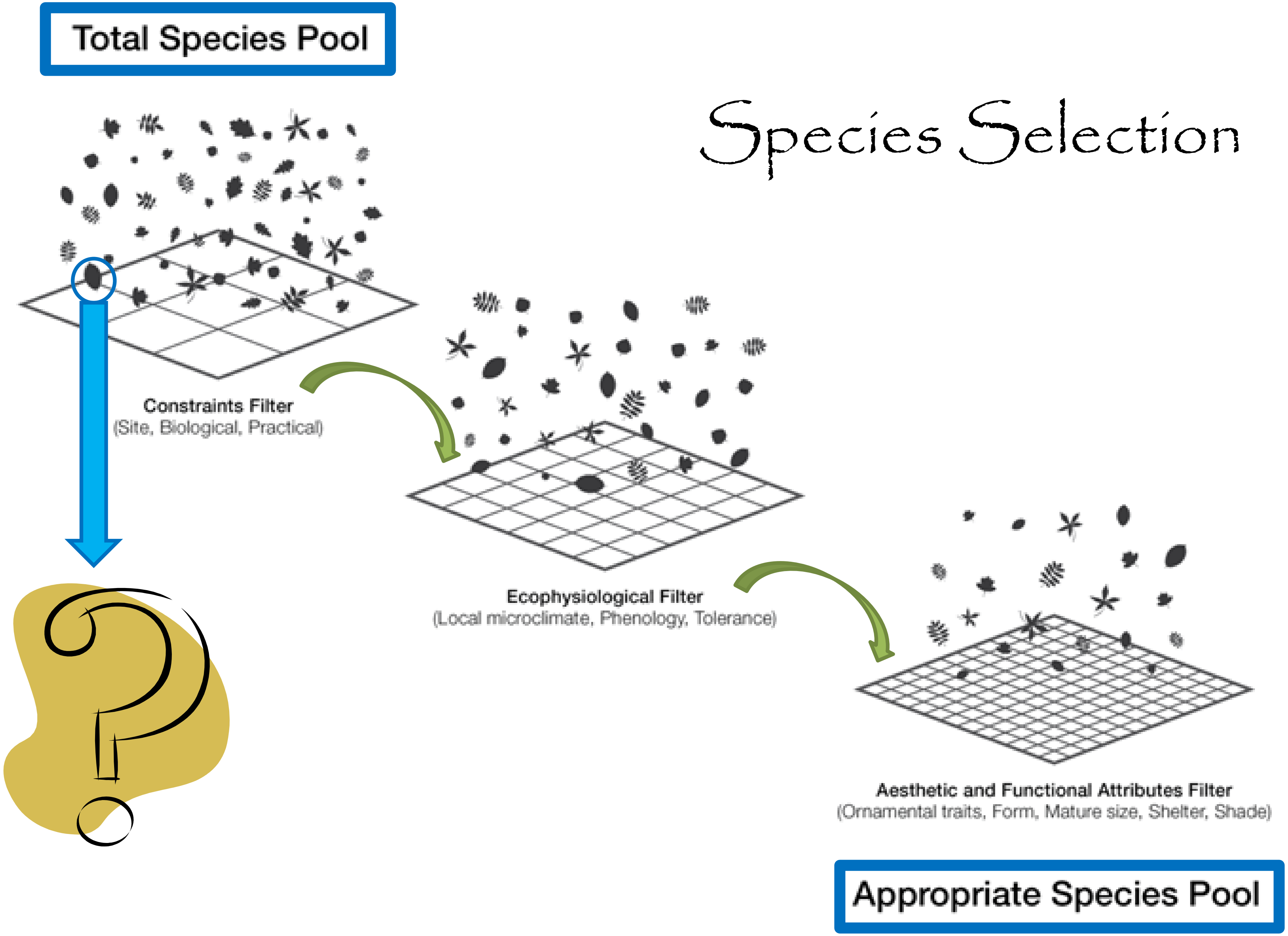
Trees & Design Action Group

Primary Project Funder
NERC SCIENCE OF THE ENVIRONMENT

Academic Partners
Lancaster University
University Centre Myerscough
SLU

Guidance Sponsors
Arboricultural Association trees.org.uk
HTA
Royal Horticultural Society Sharing the best in Gardening

Species Selection



Hirons and Sjöman 2018