Soil Issues for the Urban Forest: The care of tree rootzones

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Abstract

The retention of existing trees in developments and the planting of new trees to enhance aesthetics and urban ecology require careful thought to the needs of the tree. Recent research and understandings of tree root physiology is allowing us to plan better rootzones for our urban forest. The great enemies of established rootzones are compaction leading to reduced aeration, reduction in exploitable volume due to installation of hard surfacing and services, and changes in hydrological regime.

A tree in its natural environment establishes a "root plate" which can be very shallow (200mm) and very wide (up to 5 times wider than tree height). Old practices of considering the rootzone only out to the "drip line" provide inadequate root volume for tree longevity. Established remnant trees suffer lowered longevity due to compaction of the natural soil, burial of the root plate due to level changes, and a range of other soil problems. Allowing sufficient rootzone for the tree, enhancing the remaining rootzone, and avoiding damage during construction, are critical to the retention of remnant trees.

Techniques for improving the condition of older trees in degraded soil environments are becoming better established and some remarkable success stories are emerging where, even 5 years ago the tree would simply be removed. These techniques are a direct result of considerations over root physiology and the needs of roots.

New tree plantings in urban developments require appropriate species selection for the given soil conditions and volumes and soil modifications ranging from simple fertiliser amendments up to highly engineered "gap graded" or "structural soil" instalments in highly urban situations.

By considering the needs of the tree's roots, and not its above ground form, we can best plan to allow the tree a living space and provide all the benefits that trees bring including reduced erosion, shade and shelter, habitat, reduced wind velocity and aesthetic pleasure.

The Rootzone

The fundamental requirements of tree roots are both physical and chemical and these requirements are interrelated. Physical fertility is the ability of a soil to provide water, air, nutrients and structural support to the plant. Important aspects of soil physical and chemical properties related to tree root growth are -

1. Water holding and supplying ability
2. Gaseous exchange, ie oxygen diffusion.
3. Resistance to root penetration (compaction and soil strength.)
4. Physical support
5. Balanced soil chemistry and nutrient levels.

Coder (1998) gives a number of soil properties required for root growth and functional requirements. This is collated in Table 1.

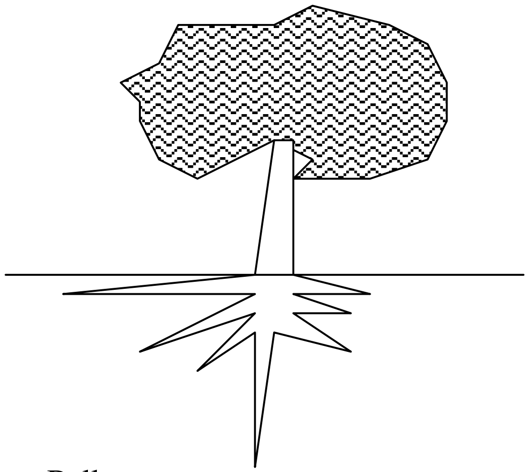
<u>Table 1. Soil Properties for Root growth and function.</u>

Soil Property		minimum	maximum
Oxygen in soil atmosphere			
	survival	2.5%	21%
	growth	5%	21%
	root initiation	12%	21%
	nutrient absorption	15%	21%
Bulk Density	Sands	N/A	1.8g/cc
	Sandy loams		1.7
	Loams		1.55
	Clay Loams		1.5
	Clays		1.4
Air Space	Sand	20-24%	NA
	Loams	14-20%	
	Clay loams and Clays	11-14%	
Water Content		12%	40%
Temperature		4ºC	34ºC

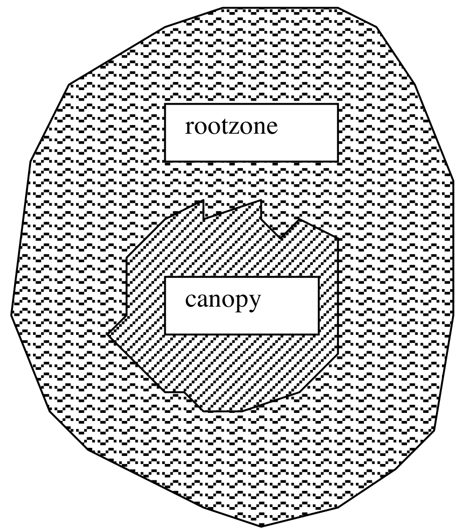
It is not difficult to understand that water content, density and air space affects oxygen diffusion and hence the requirements are interrelated. Clearly, roots grow and concentrate where an optimum level of these factors occurs. In nature the interaction of these factors results in a very typical pattern of tree root distribution.

The distribution of soil oxygen levels is the primary determinant of root distribution and studies over the last 10 years have firmly established that trees develop a root plate, not a root ball. There is no validity to the concept of the edge of the leaf canopy being the zone of maximum root development, and nor is the concept of a "taproot" valid except in very deep sandy soils with good aeration and in some desert species. Fig 1. illustrates the errors that have been made in the past and shows the more correct picture.

Figure 1. Two Common Myths about tree roots (after Matheny and Clark 1998).

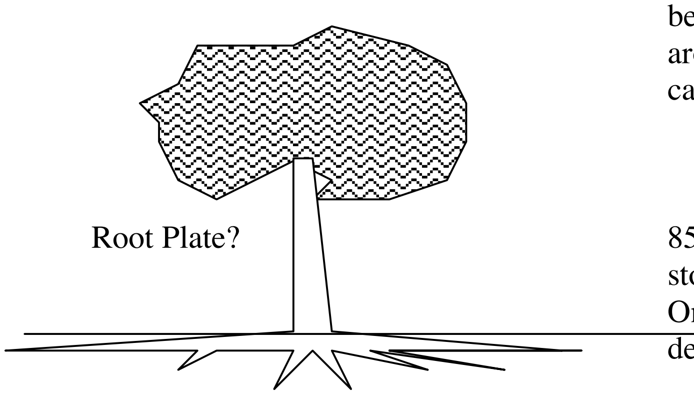


Root Ball



Roots only extend to the drip line? Nonsense, tree roots extend far beyond the crown and occupy around ten times the area of the canopy, usually asymetrically.

or



Root Plate?

85 % of all felled trees in the London storm showed a strict root plate. Only 2.5% showed any tap root development at all.

Unfortunately for urban trees the lateral spread of the rootzone is far more important to its survival, continued structural integrity, and appearance in the landscape than the depth of the soil. Below about 300mm in our shallow coast podsolic soils there is simply not enough oxygen for tree roots to live, and the roots instead grow laterally to exploit more soil. It is not uncommon to find the feeder roots of large eucalypts up to 50 metres from the trunk.

Preserving as much lateral distance from the tree, preserving soil properties within that lateral space, or manipulating and engineering a new rootzone is the key to saving existing trees, and planting new ones. Our relatively new understanding of tree root distribution and the needs of tree roots has allowed us to greatly improve our understanding of tree preservation and growth on developed land.

Existing trees in the landscape.

There are some very good texts now available on the preservation of trees during development. Matheny and Clark (1998) is possibly the best and an essential text for all landscape planners.

The first rule is to decide if the tree is worth preserving either because of any faults it may have, or because there is no hope, given the nature of the development, that an adequate rootzone can be established post development. How often do we see trees preserved by Council directive that have 100% of their effective rootzone destroyed, or a service installed to 500mm close to the trunk destroying all structural roots on that side, and effectively eliminating 50% of the active rootzone.

General rules for tree preservation when it has been decided to retain a tree or group of trees are-

1. Preserving the rootzone is as important as preserving the tree. Reserve as much surface area as possible. The largest trees need at least 12 metres of intact soil measured form the trunk.
2. Strictly eliminate all access to the preserved rootzone. You will have to be a real Nazi in this respect. Fences capable of keeping out elephants are needed. Builders do not understand trees, do not care, and are focussed on getting their job finished. They will damage cambium, compact soil, tip rubbish and cement wash water, and generally degrade the rootzone.
3. Eliminate all filling or alteration of the preserved rootzone. Even small amounts of fill placed over an intact rootzone can prove fatal to trees, the older they are the more susceptible.

In the post development phase careful thought needs to be given about the likely future of the preserved rootzone. Table 1 should be cause for concern given that we often find densities in loamy topsoils from urban parks established on intact soil with remnant trees in excess of 1.6g/cc as often as high as 1.8g/cc. No root can grow or function properly at these densities (read low airspace and hence low oxygen levels). This is the most common cause of decline in preserved trees especially in public parks.

This problem can be reduced by ongoing protection of the rootzone using techniques such as using the rootzone as a planting bed for shrubs, keeping it mulched, or using fencing. You might have noticed if visiting old historic trees such as the “Bird Tree” at Buladelah NSW, that access by pedestrians to rootzones is strictly prevent these days. Pedestrian traffic on natural soils is fatal to tree rootzones.

Quite often the decision must be to preserve trees which then slowly decline, particularly our Eucalypts which are intolerant of rootzone changes. If soil preservation techniques are not perfect there must be a plan to replant as the trees decline. Replanting can occur with trees known to be more tolerant of compaction and low soil oxygen. Tables of trees suited to urban conditions (eg Matheny and Clark 1998 and Bradshaw et al 1995, and Watson and Himelick 1997) usually focus on Northern hemisphere species and given the almost complete lack of research into our native trees (Burnley College Vic excepted) there is very limited data available. Considering the limitations of urban soils it would be logical to think in terms of those species capable of tolerating waterlogged (ie low oxygen), or high density conditions. The Melalaucas, Casuarinas, E. camaldulensis, are known to tolerate low oxygen, Iron barks and Turpentines appear to tolerate very compacted soils of high density.

Another critical requirement where rootzones have been affected or diminished is to enhance the remaining rootzone so that the tree have some chance of compensating for the loss of part of its rootzone. You will see many fatuous arguments on the benefits of fertilisers to trees. A logical approach is that if half the root system has been removed it would pay to enhance the fertility of the other remaining half. Table 2 is a guide to obtaining the correct chemical properties for most trees-

Table 2. "Ideal" physical and chemical properties for tree roots.

Property	Ideal range
pH	5.5-6.5
Salinity	<1.0 dS/m 1:2
Exchangeable sodium	< 15%
Exchangeable Calcium	65-75%
Exchangeable Aluminium	<2%
Available phosphorus	10-50 mg/kg Bray No 1 extract*
Organic matter surface 100mm	5-10%
Total Nitrogen	0.2-0.4%
Available Nitrogen	20-50mgN/kg as nitrate

* the lower level is probably more appropriate for eucalypts

Additional watering, remediation of compaction, improvement to surface drainage and runoff to prevent waterlogging are all fairly simple measures that will help wean the tree onto its remaining root system.

In recent examples we have seen remarkable improvements in declining trees by application of these soil principles. The simplest process is to exclude traffic and mulch the tree rootzone. Hard, compact topsoil devoid of organic matter cycling is not conducive to root function.

Testing the soil for density and nutrient levels is the first step. Specific deficiencies can be improved with appropriate fertilisers, and a mulch layer will encourage soil organisms to do the work of improving density.

In more extreme cases soil can be physically relieved of high density by forking, coring and aerating, or even by removal of compact soil and installation of gap graded sands (see below).

Rootzones for New Plantings.

When considering installations of new trees our new understanding of rootzone physiology has allowed us to greatly improve the access roots have to their vital needs. This improves growth, increases longevity, and can improve the interaction between buildings, installations, and trees roots. The key is to "wrap" that vital root plate zone around into a shape that fits into the urban soil profile while continuing to provide the aeration needed to keep the roots alive.

The degree (and hence expense) of such manipulation can be summarised as follows (in increasing order of cost and engineering difficulty-
1. Species selection. Tables of trees tolerant of compaction and low soil aeration, the usual urban soil problem, are available. When budgets are limited this is the most appropriate technique. We are often astounded by how some trees grow at all in somesoils but they do, albeit not to their full potential. Celtis and Melaleuca show remarkable tolerance to growing straight in urban pavements surrounded by hard surfacing.

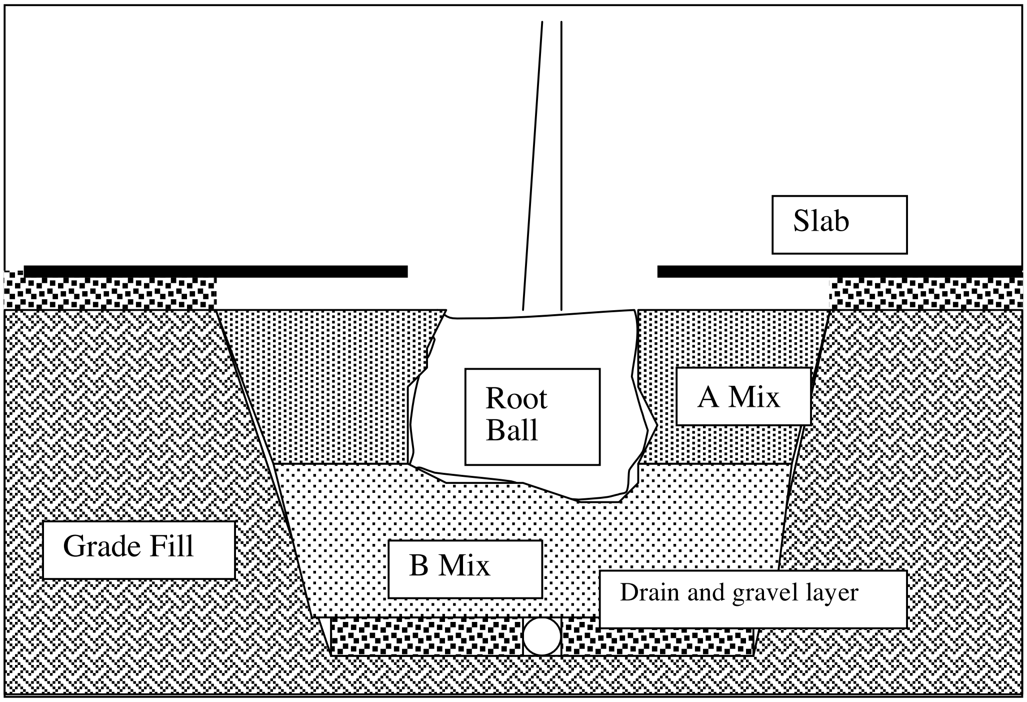
2. Changing the topsoil. Table 1 shows clearly that a sand has greater pore space at a given density, and is likely to provide better aeration and pore space than other soil textures under the same compaction regime. Sands are "compaction proof" in that they can be heavily compacted and still maintain 20% pore space minimum. Thus removal of the surface 100-200mm of topsoil and replacement with a sandy rootzone mix as used to prevent compaction in the turf industry can bring significant advantages. Even where trenches of sand are installed radiating out from the planting hole, improvements could be expected. By increasing the depth of the sandy layer to, say 400mm, the greater depth may partially overcome a restricted rootzone area. There is merit in adding organic matter and nutrients to the sandy replacement mix.

Important Note for Engineers: If you want to encourage root invasion of services use a friable sandy fill to backfill them. This is probably better aerated than the site soil and will result in a rush of roots to the favourable oxygen levels found. Use an evenly graded silty loam wel compacted to exclude pore space and the problem will lessen.

3. Vault planting. A highly engineered solution, the construction of a vault is typical of solutions to problems in interior or "on slab" landscapes, or in highly built up situations such as city trees where so many services and hard surfaces exist that no lateral rotzone can be provided.

Possibly the most expensive installation, the vault is being replaced by structural soils on grade plantings but the vault or planter box still remains as a solution to interior landscape problems. The essential difference between a vault and a structural soil is that with the vault a concrete slab takes the load from traffic and paving, whereas in a structural soil planting the soil takes the weight. Figure 1. Gives our recommendation for such vault installations.

Figure 1. Soil recommendations for Vault installations.



Soil Specifications-

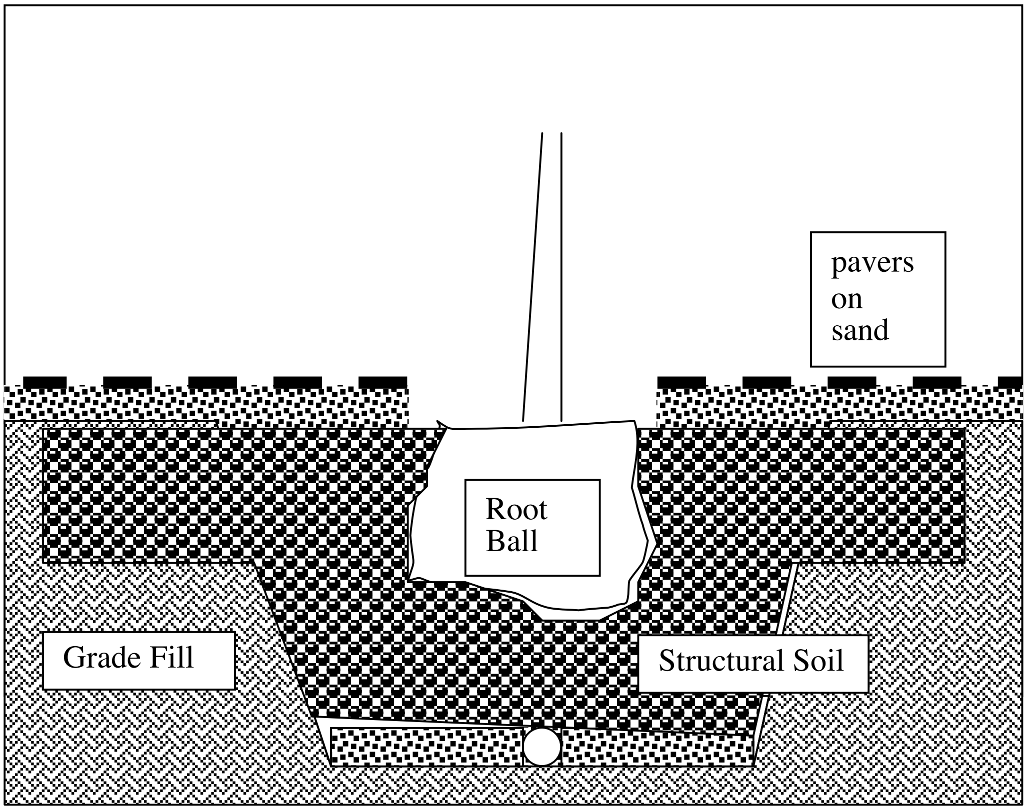
A Mix: Organically enriched sandy loam up to 20% organic matter. No deeper than 300mm. Fertilisers recommended.
B Mix: Sandy loam mix with no organic matter.

This design is essentially the same in principle as the Amsterdam Tree Soil specification of Couenberg 1993.

Remember that the design must introduce as much air as possible into the subsoil layers since we now have a root ball not a root plate. Burying organic matter in the subsoil exacerbates oxygen depletion. Also remember that the drain is in fact an air entry point as well and should be exposed to the free atmosphere at some point. If this is not possible then install an additional aeration pipe the whole depth of the vault or planter.

Structural soils are a solution to the problem of rootball development in a highly urbanised situation. Figure 3 gives an idea of how they work.

Figure 3. Schematic Structural Soil installation .



A structural soil is a unique blend of weight bearing rock and filler soil. We have found 65mm basalt aggregate top be ideal. We used enough filler soil to fill about 1/2 to 2/3 of the pore space in the aggregate. With angular aggregate this is around 20% by volume. We chose a rather clayey filler soil to maximise nutrient and water holding ability. There seems little point in using sandy loams as originally specified since compaction is not now a problem.

The use of a structural soil is only appropriate where severe weight bearing must be taken by the soil. There is no point, for example, in using it in median strip plantings where traffic does not occur. The technique allows us to establish larger rootzones in highly complicated shapes wrapped around services.

These are the important principles pertaining to root growth in urban soils and a few examples of possible solutions. There are many other solutions but by understanding the principles and getting some help from an urban soil scientist cost effective and useful solutions to individual problems is possible. Remember, if a tree looks poor, scappy, or declining, look at its rootzone, forget about the upper parts, they can regrow if the soil environment is suitable.

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