



Sydney Environmental & Soil Laboratory

Specialists in Soil Chemistry, Agronomy
and Contamination Assessments

Soils and Tree Roots: Principles and Practices Related to the Care of Trees

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The soil medium is something that affords the tree root system an optimal supply of-

1. oxygen and gaseous exchange
2. moisture availability
3. nutrient supply
4. ease of extension.
5. anchorage to a firm base.

1. oxygen and gaseous exchange

Gases diffuse through pores and voids in the soil. Compaction by traffic reduces the amount of pore space and thus the gaseous exchange rates leading to a reduction in the depth at which roots can effectively function (distance from a free atmospheric surface decreases). Excessive use of mulches can have a similar effect as can burial of reducing substances (like compost), that consume oxygen and produce carbon dioxide, smothering the root.

2. moisture availability

Water displaces air in soil reducing the amount of pore space and effective diffusion of gases. Thus in water logged soils roots must grow very shallow to obtain enough oxygen. Ironically, a plant wilts in waterlogged conditions. In compacted soil the smaller pore space is more easily filled with water, further reducing pore space and rooting depth. On the beneficial side water is needed for plant growth and a compacted soil not only reduces infiltration (lowering the effective rainfall at the site) but it dries out more quickly. Thus compaction, the greatest urban soil problem leads to a decrease in effective rainfall.

An important factor is also the species mix, particularly in altered natural environments. Unfortunately Pittosporum and Privet (*Ligustrum*) can extract water to greater tensions than the non drought tolerant Eucalypts and thus the dieback of Sydney Blue gum forest with privet or Pittosporum weed invasion is an all too common sight.

Thus reduced drainage, alienation of parts of the rootzone by built structures, compaction, and weed invasion, can lead to reduced water availability.

3. nutrient supply

Disturbance to the natural cycling of organic matter on the forest floor disrupts the trees access to the nutrients it needs and the natural “bioaccumulation” of limiting elements. A truncated rootzone obviously leads to a lower exploitable root volume and thus less available nutrients. The addition of pollutants and even ill conceived fertiliser or mulch programs can further limit the trees ability to access the nutrients it needs. For example a very woody mulch can cause nitrogen depletion in the soil.

Scalping and erosion can remove the precious topsoil layer containing most of the nutrients and have a severely debilitating effect on a mature tree’s health, and the growth rates of newly planted trees. Plant roots grow best in the following chemical “window of life”-

Table 1. Normal Ranges for “Healthy” Soils

Analyte	Ideal Range	Comment
pH	5.0-7.0	Wide tolerance in trees even within species
Salinity ECe dS/m	generally < 10	much higher tolerances available
Cation Exchange Properties		
	% of CEC	
Sodium	< 5	Sodium causes poor structure
Potassium	5-10	Lower amounts in heavy clays
Calcium	60-75	Calcium must be 3-6 times the Mg level
Magnesium	15-25	Important in chlorophyll production
Aluminium	<2	Toxic element in larger amounts but tolerated by many species.
Phosphorus in the Bray No 1 extract		
	mg/kg of P	
	0-5	inadequate for all but some native plants
	5-10	adequate for park trees or rough grassing
	10-20	high status forest soil
	20-40	Vigorous turf
	40-80	Annuals and bedding plants
	> 80	excessive in almost all situations.

Nitrogen, and sulphur availability are not easily determined for either trees or any crop. The following is a rough guide to soil status.

Total N %	
< 0.1 %	very low N consistent with heathland and deficiency in most species.
0.1-0.2 %	Most Australian soils, reasonable growth of

0.3-0.5%

long lived woody species.
High fertility soils. Rapid growth in responsive species.

Trace elements are rarely a problem in urban soils and usually deficiency is not the greatest problem. An exception here is iron which can become chronically deficient in soils affected by lime and/or excessive phosphorus levels.

I think that there isn't a better example of soil conditions related to the status of vegetation than the work of McColl, J.G. (1969) who related soil conditions to vegetation status.

Fig 1. Soil Conditions Related to the Status of the Vegetation

Determinant	E. gummifera Open woodland. Ridges	E. Saligna Tall forest Gullies
pH	4.45	5.82
Total P in Topsoil ppm	170	469
Exch Cations kg/ha 0-61 cm		
Na	94	443
K	430	1217
Ca	470	5032
Mg	765	3925
Al	4538	420
Ca/Mg by mass	0.61	1.3

Source: McColl, J.G. (1969) *Soil-Plant Relationships in a Eucalyptus Forest on the South Coast of NSW. Ecology*, Vol 50, No 3.

The obvious conclusion from this work is that the closer a soil is to the "ideal" the better the growth of plants generally and that the environment moves toward a species mix capable of exploiting the environment fully. Thus, except for a few species, the "urbanisation" of soil resulting in a rise in pH and phosphorus status (as well as nitrogen) should result in better tree growth all other things being equal.

Unfortunately this is seldom the case as other factors such as compaction become more limiting. Fortunately, with the advent of modern fertiliser availability, non optimal nutrient and chemical conditions are easily rectified if the right soil information is available and in our view it is essential in all cases to relieve trees of nutrient stress so that they can better resist other stresses.

4. ease of extension.

Roots can exert great pressures on soil while trying to elongate, and some exert greater pressure than others. While the tree is trying to develop a new root system in the post development landscape, the natural depth at which it soil like to establish its roots can be opposed by compacted soil, barriers, concrete, paving etc. Compacted soil is strong and resists root penetration thus roots trying to grow nearer to the surface in a compacted soil can be prevented from doing so by the strength of the compacted soil surface.

5. anchorage

A tree that has established a shallower root system as a result of compaction and drainage problems will have suffered root death at depth and thus be less well anchored. It was obvious to me during the aftermath of the severe wind storms in 1991 in Sydney's North Shore that those trees most prone to being felled were those in drainage lines where poor drainage combined with increased urban run off of water lead to a wet soil with a shallow root system. Symptoms of epicormic growth and poor canopy health is the outward symptom of this decline of the roots.

The particular mix of these five factors determines what natural vegetation will establish on a site and the exclusion of one type of vegetation over another has more to do with tolerance rather than preference. That is to say, some vegetation types tolerate poor or suboptimal soil conditions better than others and hence come to dominate. It is not the same as saying, for example, that heathland plants prefer low soil fertility. They can simply tolerate these conditions better than other plants and hence show a selective advantage. It should be quite obvious to an arborist that some species, a good example being *Melaleuca* spp grow only in water logged situations in nature but grow very well as a street tree in a range of well aerated soils.

There are several situations where our laboratory gets involved in the science of planting, improving, or designing for trees in the urban setting-

1. Improving and rectifying soil for existing (often mature) trees.
2. Improving (natural and disturbed) soils before planting.
3. Designing soils and soil systems for new plantings.

1. Improving and rectifying soil for existing trees.

For established remnant trees urbanisation of the natural soil system has the potential to change the mix of soil factors such that the new environment may no longer be tolerated by the species. Sometimes death in a tree presented with changes with which it cannot cope is imperceptibly slow and is usually labelled "reduced longevity" and is not attributed to anyone in particular's fault.

The surface 200mm of a soil is, unfortunately, the most sensitive to urban disturbance. The most important changes instigated by urbanisation are-

- compaction by traffic including pedestrians leading to reduced infiltration of water and decreased gaseous exchange rates.
- a rise in soil pH (lime accompanies Man)
- a rise in soil phosphorus levels through manure and litter and the high P levels in most non specialist fertiliser mixes.
- scalping of topsoil either deliberately or by erosion leading to loss of accumulated nutrients, organic matter and “topsoil properties”, confinement of roots to “subsoil properties”
- burial by fill brought in to raise levels. Topdressing lawns etc all resulting in a reduction in gaseous exchange rates.
- significant reduction in the available soil volume by alienation of soil through services, installations etc.

The root system of a tree is dynamic (Watson 1990) and changes its depth of maximal activity according to season, moisture, and oxygen availability (physical properties). Nevertheless, the location and depth of major roots cannot change overnight and rapid alterations are often fatal.

Chemical alterations are often tolerated to a greater extent and a slow and steady decline in topsoil nutrient levels results at first in a slowing in growth rate until the tree actually declines.

2. Improving (natural and disturbed) soils before planting.

Our approach is generally to establish (if we do not have one already) an essentially natural soil profile with coarser and more sandy material as an A horizon, and a more clayey subsoil or fill layer at depth.

The fill and topsoil should show the cation exchange ratios of good quality soil and a variety of lime, gypsum, dolomite and other ameliorants are available for this purpose.

Where conditions are severe, for example salinity in subsurface fill and no possibility of rectification the only practical solution is to choose tree types which can tolerate the given soil conditions.

The other aim we have is to allow the basic soil processes of organic matter and nutrient cycling to occur as far as possible. This ensures as little maintenance as possible. For example, if a healthy mulch layer is used to “kick start” an ecosystem on fill or excavated material, the basic nutrient deficiencies are addressed, and an attempt is made to include a diversity of plants including legumes in the species mix, the landscape should be almost completely self sustaining.

3. Designing soils and soil systems for new plantings.

Sometimes we have the luxury of completely designing the entire soil system for an intended planting. This is usually in the higher value jobs and in difficult situations such

as an absolute lack of soil, very intense traffic, or in interior landscapes. Some examples are-

- Construction of “facsimile” soil profiles following natural soil principles at the Homebush bay Olympics site. A heavily disturbed environment with no natural soil remaining and only fill and excavated geological material to work with.
- Use of Structural and other “gap graded” soils designed with very specific parameters in mind including absolute incompressibility.
- Use of confined rootzone mixes (potting mixes) in interior and exterior landscapes notably Sydney’s Capita Centre and Casino plantings. Longevity of the mix is a major consideration.

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