Raising Trees: A Guide to Preventing Soil Compaction During Construction

Soil compaction is the quiet killer of trees. Unlike visible tree damage, such as topping, trunk girdling, or root pruning, soil compaction is nearly invisible but no less lethal. Compaction is caused by soil particles being squeezed together. This process removes air spaces making soils denser, oxygen deprived, and less able to absorb water. Resulting soils are limited in their ability to support tree roots and soil life of all kinds. Soil compaction is usually hard to reverse. Treatments are expensive and often not very effective, so protecting the soil is by far the cheapest and easiest way to keep trees healthy.

When does soil compaction around trees occur?
The most likely time is during new home construction or when remodeling of some type occurs near trees. Other causes of compaction are hardscape or landscape modifications such as driveways, sidewalks, or patios. In actuality, any time that equipment, vehicles, or people are driving or operating under trees, there will likely be soil compaction, leading to unhealthy and possibly dead trees.

Why is preventing soil compaction around trees important?
Trees provide many benefits, including higher property values, cleaner air, lower power bills, better health, and more economically robust communities. Many people view a tree-shaded home on a tree-lined street as an ideal living space and are willing to pay extra for it. That is why some new building sites are being purposefully selected for their existing trees. Unfortunately, the very trees for which these sites are selected can be killed by modern construction activities. The purpose of this publication is to educate the public in how to avoid compaction that leads to tree death and to make the sight of damaged or dead trees in construction areas a rare one.
How do construction practices increase soil compaction?

Compaction severity is related to the force applied to the soil, how often force is applied, and soil characteristics such as texture, moisture, and surface cover. Soil compaction is an unintended consequence of building construction and affects not only preexisting trees but also newly planted trees as well.

The force needed to cause soil compaction can come from heavy equipment, passenger vehicles, stockpiled supplies and equipment, and even pedestrian traffic (figure 1). The heel of a human foot can exert as much pressure as a small pickup truck, approximately 25 pounds per square inch (psi). The pressure, or psi, applied is important, but so is the frequency or duration of the pressure. Over time, seemingly insignificant activities such as parking vehicles and walking under trees add up.

Frozen and dry soils are generally resistant to compaction as are coarse-textured sandy soils or soils high in organic matter. With rain, however, the extra soil moisture makes most soils far more susceptible to compaction.

Figure 1. The force causing soil compaction is measured in pounds per square inch (psi). Both the psi and frequency or duration of the pressure are important.
Tree shade keeps machines, vehicles, workers, and storage cool but costs the tree its health.
How does soil compaction affect tree health?

An ideal soil for tree roots is composed of 50 percent pore space for holding water and air; 45 percent minerals composed of sand, silt, and clay; and 5 percent organic matter. As compaction reduces this pore space, root growth slows. Root growth drops to zero when soils are compacted to only 12 percent pore space.

Compaction studies have shown that the worst compaction from construction generally occurs in the top 4 to 10 inches of the soil profile. Because the majority of tree roots are concentrated within the top 18 inches of the soil surface, this is a serious problem for trees.

**Common Problems with Soil Compaction**

- Short, stunted roots
- Increased water runoff and decreased availability of water to roots
- Limited air infiltration, which leads to high levels of carbon dioxide in soils, causing shallow and less stable root systems
- Increased root conflicts with surface infrastructure and landscaping
- Reduced drought tolerance
- Increased root damage from lawn maintenance equipment

“\(\text{It's not the years of traffic, but the first few trips over a site that do the majority of compaction damage.}^\)”

Kim Coder
University of Georgia

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**Four Principal Components of Soil**

- 25% Air
- 5% Organic Material
- 25% Water
- 45% Mineral
Construction-damaged roots provide a pathway for tree disease.
Soil compaction affects trees in three primary ways:

**First**, the loss of pore space slows water movement through the soil, decreasing available water for roots and increasing runoff. Water deficiencies reduce photosynthesis and eventually cause a loss of leaves. It is not uncommon to see yellowing and patchy canopies in trees growing in compacted soils. Tree wilting on compacted soils is common during dry summers and prolonged droughts.

**Second**, the loss of pore space reduces oxygen available to roots. Lack of oxygen interferes with tree relationships between their roots and oxygen dependent microbes. Also, without oxygen roots are unable to convert sugars into energy for growth, resulting in reduced nutrient absorption and eventually root death.

**Third**, soil compaction becomes a physical barrier to root growth. To compensate, trees grow roots on or near the soil surface, making them more susceptible to temperature changes and drought. Surface roots are also subject to mowing damage and crack hardscapes, such as driveways, sidewalks, and streets. Surface-rooted trees are also less stable and can topple in windstorms.

In summary, soil compaction is damaging in many ways to both existing and future trees in the landscape. It truly is the silent killer. The most obvious and economical solution is prevention.
Tree roots are typically shallow and easily damaged by digging and soil compaction.
How do you prevent soil compaction around trees during construction?

Tree preservation is directly related to soil preservation—protection of the soil from the movement of equipment, materials, or personnel over the root zone. If a tree’s roots and the soil they inhabit remain undisturbed, the tree is likely to survive construction. But how much of the tree’s root system needs to be protected?

The minimal rooting area that should be preserved to ensure a reasonable expectation of the tree’s survival is called the **critical root zone (CRZ)**. The size of the CRZ depends on the age and health of the tree and the tolerance of the species to injury (construction damage). The radius of a CRZ is some multiple of the trunk diameter at breast height measurement (DBH), which is measured with a diameter tape at 4.5 feet from the ground. The average distance is 1 foot for every inch in DBH. Young, healthy trees of species with high tolerance for construction
Critical root zone too small—extensive root loss to soil compaction
A group of trees sharing critical root zone space

damage require the smallest CRZ. These young trees need only half the normal CRZ radius or 0.5 feet per inch in trunk DBH. Overmature trees of species with low tolerance to construction need the largest CRZ. These old trees need a zone 50 percent greater than average with a multiplier of at least 1.5 feet for each inch in trunk DBH.

- Arborists define a **tree protection zone (TPZ)** as the boundary around a tree(s) designed to protect the critical root zone. Tree protection zones may be as small as a CRZ for a single tree or much larger to contain the CRZs of multiple trees. The area contained by a TPZ is more than a multiple of the trunk diameter at breast height (DBH). A TPZ contains **at least** the critical root zones of trees being protected.
- TPZs often contain more area than CRZs demand. The larger the TPZ, the more successful the tree preservation will be.
- TPZs exist to minimize construction damage to trees. The boundaries set as the TPZ must be respected by all workers and subcontractors. Point this out to anyone working on site.
- A TPZ, particularly in dense building sites, should contain excess soil area to allow for future tree growth. Trees that survive construction will continue to grow and require more resources; forward planning for the future of the tree is a part of the TPZ.
CRZ Guide

- **Young and Healthy**
  Allow 0.5 foot radius per DBH inch

- **Mature and Healthy**
  Allow 1.0 foot radius per DBH inch

- **Old and Unhealthy**
  Allow 1.5+ feet per DBH inch
  (Note: Large, older trees or trees in poor health will require as much CRZ as can be allowed. Consult an International Society of Arboriculture (ISA) certified arborist to determine tree health.)
To protect the soil and roots within the CRZ, erect fences around the perimeter of the TPZ. Ideally, no one should enter the TPZ. Circumstances often arise, however, that make it necessary to temporarily cross the TPZ. Special protections are needed to reduce the compaction and root damage that occur from traffic over the critical root zone during construction.

**Temporary Techniques and Materials for Crossing Tree Protection Zones**

**Technique 1: Use Mulch for Light Traffic Areas**

One of the simplest ways to reduce soil compaction is to apply an 8-inch-deep layer of chipped wood mulch over the tree protection zone that is temporarily open to construction traffic. The mulch may include wood directly from a chipper (generally between ½ and 2 inches in length) and does not have to be designed for plant health. Pine straw, pine bark, or other refined mulches have limited or no effect—the mulch must be chipped wood. This technique is ideal for areas with only light traffic, including pedestrians and small vehicles.

Coarse mulch is best for temporary passages. Mulch fresh from chipping works well.
Use finished finer mulch at a depth of 3 inches for foot traffic.

For temporary machine crossings, use coarse mulch 8 to 10 inches deep.
Helpful Tips

- For temporary passages (those to be used less than 6 months), use raw, coarse mulch.
- For semipermanent or permanent passages (those that will be used 6 months and longer), soil pH changes and nitrogen uptake by the raw wood chips become a tree health concern. Use wood chips that have aged at least 5 months, which is long enough for the mulch to become more pH neutral and be colonized by bacteria and fungi.
- If vehicles will be turning on top of the mulch passage, consider installing chain link or welded wire fencing on top to hold the mulch in place. T-post stakes can be used to secure the edges of the fencing along the route.
- Over time, the applied mulch will spread or wash away, so it is important to ensure that areas under traffic retain at least 8 inches of mulch at all times.
- At the conclusion of the project, reduce the mulch thickness within the tree protection zone to no more than 3 inches.

Technique 2: Use Geotextiles Plus Mulch for Medium to Heavy Traffic Areas

Geotextiles developed for supporting structures are now being used as antisoil compaction tools. Geotextiles come in many different forms and are typically used to underlay roadways and foundations or add stability to landfills. The most commonly used geotextile is triplanar geocomposite (e.g., Tenax TenDrain, Terram Geocells, GSE Coaldrain) consisting of two layers of spun, bonded fabric with a force-spreading semirigid plastic panel in between that also allows for drainage and air movement.

The geocomposite is laid down on the soil surface, secured, and used in combination with an 8-inch-deep mulch layer. The geocomposite alone will have little or no effect. In fact, studies have been unable to show that this technique is more effective than simply using mulch; however, anecdotal observations indicate that in areas where equipment is making
Geotextile protection

Chipped wood mulch over tree protection zone
regular turning motions, this material can hold the mulch in place and reduce rutting and the associated compaction. This technique is ideal for light to medium traffic where regular turning motions, such as in a staging area for unloading materials, are expected.

Helpful Tips

- Pins or staples must be used to secure the geocomposite to the ground it rests on or the fabric will move as traffic rolls over it.
- An 8-inch layer of mulch must be added on top of the geocomposite.
- Geocomposite allows for easy removal of mulch because it can be peeled back to remove the geocomposite and mulch in one simple motion, thus removing the risk of damaging the roots with equipment while removing excess mulch.
- Remove the mulch and geocomposite at the conclusion of the project.

Technique 3: Use Plywood Over Mulch for Heavy Traffic Areas

Research shows that mulch under ¾-inch-thick plywood is the most effective technique for reducing soil compaction in TPZs. This technique is optimal for areas where there will be significant movement of equipment. Note, however, that plywood will break down over time and will need to be replaced periodically to retain its effectiveness. As with the two preceding techniques, mulch thickness must be maintained at 8 inches throughout the area, and at the conclusion of the project, any mulch left on site should be reduced to only 3 inches to ensure future tree health.

Helpful Tips

- The recommended plywood is ¾-inch, laminated sheets in large sizes. Thicker laminated sheets are also acceptable but are much heavier and difficult to move.
- Synthetic substitutes for plywood sheets are now on the market and can be useful replacements for plywood.
Plywood over mulch is ideal for heavy passages. The combination of plywood over thick mulch provides the most compaction protection.
Techniques for Safely Crossing Tree Protection Zones

<table>
<thead>
<tr>
<th>Technique</th>
<th>Best Use</th>
<th>Avoid</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>8 inches of mulch</td>
<td>Light traffic (pedestrians and light vehicles)</td>
<td>Heavy thoroughfare traffic and heavy equipment</td>
<td>Mulch will need to be replenished because it sinks into the soil or washes away during rain events. Make sure that 8 inches remain at all times.</td>
</tr>
<tr>
<td>8 inches of mulch over geotextile</td>
<td>Light to medium traffic including pedestrians and vehicles</td>
<td>Busy thoroughfares where heavy equipment will make regular trips</td>
<td>Geotextile requires pinning down to keep it from shifting.</td>
</tr>
<tr>
<td>¾-inch plywood over 8 inches of mulch</td>
<td>Areas with regular and heavy traffic</td>
<td></td>
<td>Plywood breaks down during use. Replacing plywood and mulch ensures that compaction-reducing effects remain.</td>
</tr>
<tr>
<td>¾-inch plywood</td>
<td>Light foot traffic and single vehicle crossings</td>
<td>Repeated crossings</td>
<td>This can be used to access trees during pruning or pre- or postconstruction work but should not be used for repeated crossings.</td>
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**Technique 4: Use Plywood for Light, Irregular Traffic Areas**

Plywood without mulch has little or no ability to reduce soil compaction. Using only plywood prevents rutting but still allows significant levels of soil compaction. The best uses for plywood over the soil include reducing compaction associated with foot traffic or irregular equipment use around trees to prevent rutting. This technique is ideal for crossing root zones to maintain trees or to perform short, irregular tasks that require heavy equipment.
The best way to prevent soil compaction is to never enter the tree protection zones.
Conclusion

All of the techniques described in this publication will reduce but not prevent soil compaction. The only way to prevent soil compaction is to stay outside the TPZ. These techniques should be used only when staying outside the TPZ is not possible. Large trees are not reparable or immediately replaceable so every effort must be made to minimize traffic and ensure that the anticompression materials used are suitable and maintained in optimal condition. Under wet conditions, it is uncertain how any of the above techniques will work out. It is likely that compaction levels will increase significantly.
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