Finding space **for trees in the city**

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Finding space for trees in the city

Nina Bassuk, Urban Horticulture Institute, Cornell University, Ithaca, NY explains the importance of finding space for trees in the urban environment

The fact that trees have difficulties surviving in urban and suburban environments is not a surprise. Urban areas are rarely designed with trees in mind. Trees are often treated as if they were afterthoughts in an environment designed and built for cars, pedestrians, buildings, roadways, sidewalks and utilities.

Urban trees face a range of environmental challenges, such as increased heat loads, from the pavement, cars and buildings, de-icing salts, soil and air pollution and interference from utilities. Yet the most significant problem that urban trees face is the scarcity of soil suitable for root growth. While many of the problems urban trees face can be mitigated by planting species that are tolerant of a given challenge, there are no tree species that can tolerate the extreme soil compaction that is prevalent throughout urban and suburban landscapes.

A large volume of uncompacted soil, with adequate drainage, aeration and reasonable fertility, is the key to the healthy growth of trees. The upfront investment in making the soil suitable for supporting a healthy tree is paid back in full when that tree fulfils the functions for which it was planted. These functions may include shade, beauty, noise reduction, wind abatement, pollution reduction, stormwater mitigation, wildlife habitat and the creation of civic identity. An adequate soil volume is key, considering that soils are where the nutrients, water and air are held in a balance that allows for root growth and water and nutrient acquisition. Simply put, when soils are inadequate, plant growth suffers and trees die prematurely.

The role of soil volume on tree growth

Human activities can severely damage soil structure. The process of construction in a city or even the installation of a sidewalk. There are two critical effects of soil compaction which directly impact plant growth and limit useable rooting space:

1. Soil structure is destroyed and the majority of large interconnected pores (macropores) are crushed. This results in a restriction of the soils water drainage and subsequent aeration.

2. As the macropores are crushed, soils become denser, eventually posing a physical barrier to root penetration. There are numerous accounts of urban soils being as "dense as bricks"

What happens when roots encounter dense, compacted soil?

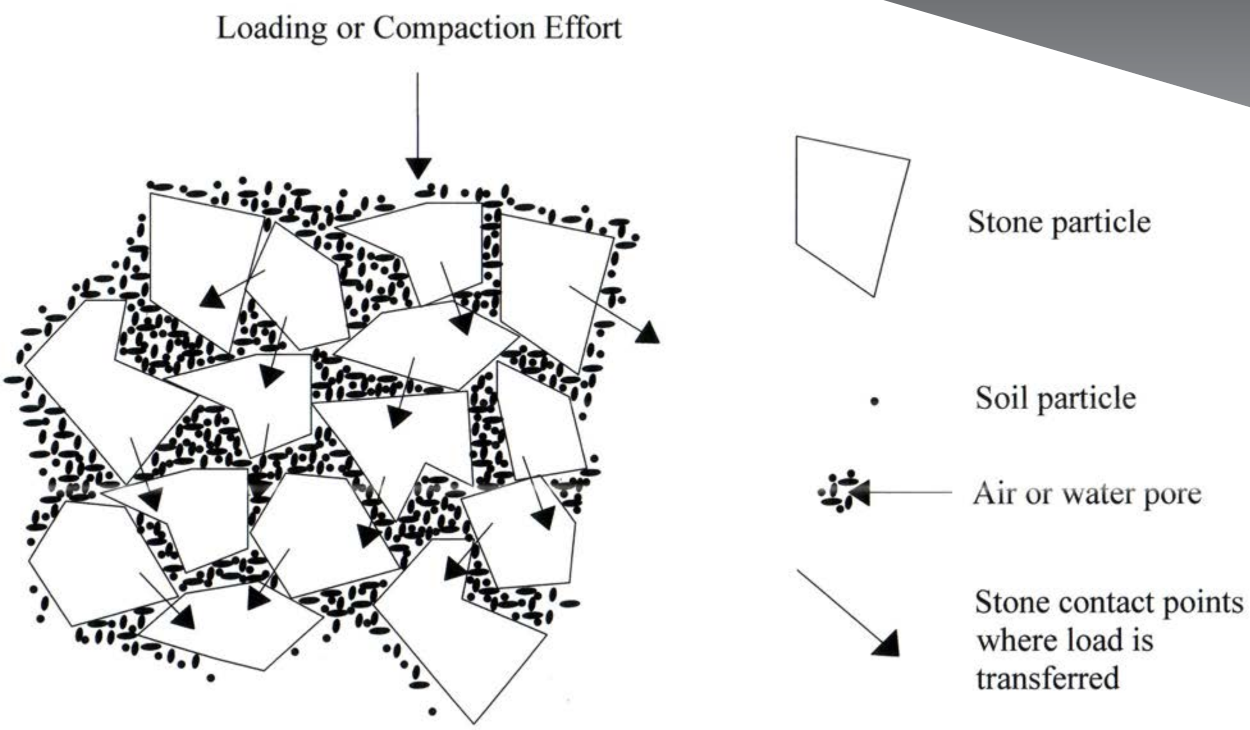
When roots encounter dense soil, they change direction, stop growing, or adapt by remaining abnormally close to the surface. This superficial rooting makes urban trees more vulnerable to drought stress and can cause pavement heaving.

In urban soils that are not covered by pavement, it is possible to break-up, amend or replace compacted soils to make them more conducive to root growth. However, where soils are covered by a pavement, the needs of the tree come in direct opposition to specifications that call for a highly compacted base on which to construct a pavement. All pavements must be laid on well-draining compacted bases so that the pavement will not subside, frost heave or otherwise prematurely require replacement. Therefore, soils that must support a pavement are often too dense for root growth. It is not surprising then that urban trees surrounded by the pavement have the shortest life spans of trees in cities. Unfortunately, these paved areas also tend to be those that most need trees to mitigate the heat island microclimates that exist in downtown areas.

How much soil volume does a tree need?

Urban trees are necessary to the health and livability of our cities, but how much useable soil is necessary to allow them to fulfil their design functions? Research at Cornell's Urban Horticulture Institute (UHI) has shown that a reasonable 'rule of thumb' for most of the United States, except for the desert southwest, is to plan for two-thirds (2/3) of a cubic metre of soil per every square one third (1/3) of a cubic metre of crown projection. The crown projection is the area under the tree canopy projected to the ground. If the tree canopy is viewed as symmetrical, the crown projection can be calculated as the area of a circle (πr2). For example: for a tree with a canopy diameter of 6-metres, the crown projection would be, 3.14 x 3^2, or 28 square metres. Using the 'rule of thumb,' an estimate can be calculated that a small

Severely compacted soil that is "dense as bricks" and not conducive to tree root growth



CU-Structural Soil® conceptual diagram

tree with a 6-metre crown diameter needs 56 cubic metres of soil to support it. Assuming a useable rooting depth of 1-metre, one way of dimensioning the space needed for this tree would be 7.5 x 7.5 x 1 or 56 cubic metres. It is clear that a typical tree 2 metre x 2 metre opening in a sidewalk is inadequate to allow the tree to mature to this size and fulfil its function in the landscape.

This 'rule of thumb' method is a very rough way to estimate the soil volume needs of a given tree. This method is based on determining what volume of water must be available in the soil for a tree to support itself and accounts for climatic factors, such as days between rainfalls when the evaporative demand is highest. This general 'rule of thumb' is misleading about how different soil types vary in their water holding capacities. For any given tree, the minimum volume of soil needed to support it will be different depending on how much sand, silt and clay make up the soil composition.

Yet another issue involves the presence of groundcovers, including a lawn. In situations where trees are sharing their soil volume with other plants, even turfgrass, there is more competition for the water held in the soil. In such cases, it is best to try to provide additional soil volume.

Where can one find enough soil?

If the soil under sidewalks and other paved areas were suitable for root growth, urban trees would potentially have access to large volumes of soil. This scenario would allow trees to grow to their mature size and perform as desired. Also, if the soil volume for each tree was connected and continuous, each tree would be able to share soil with its neighbouring tree. Looking at the forest as a model, trees may be spaced close together as long as they share a large common soil volume to support their needs.

However, given the limited space availability and the desire for roads, sidewalks and other pavements in cities, it is essential to have soil that meets engineering requirements for load bearing while simultaneously allowing for unimpeded root growth under the pavement. CU-Structural Soil is one technology that meets these requirements.

What is CU-Structural Soil®?

CU-Structural Soil is a two-part system comprised of a rigid stone "lattice" that meets engineering requirements for a load-bearing paving base and a quantity of uncompacted soil that supports tree root growth. The primary component of this soil system is a uniformly sized, highly angular crushed stone ranging from 2-3 centimetres in diameter, with no fine materials. When this narrowly graded

Zucotti Park in New York City. Trees in CU-Structural Soil

stone is compacted, the stones form an open "lattice" structure with about 40% porosity. Friction at the points where stones come in contact with one another allows the creation of the load-bearing structure of the CU-Structural Soil.

The second component of the system is a soil which fills the voids in the stone "lattice". As long as care is taken to not add too much soil to the mix, which would prevent the stone structure from forming, the soil in the voids will remain non-compacted and root penetrable. Among soil textures, clay has the most water and nutrient-holding capacity. A heavy clay loam or loam, with a minimum of 20% clay, is used in the CU-Structural Soil system. A minimum of 20% clay is also essential for an adequate storage of nutrients. It should also have organic matter of 5% to ensure nutrient and water retention while encouraging beneficial microbial activity.

With carefully chosen uniformly-graded stone and the proper stone-to-soil ratio, a medium for healthy root growth is created that also can be compacted to meet engineers' load-bearing specifications. The intention is to "suspend" the clay soil between the stones without over-filling the voids, which would compromise aeration and bearing capacity.

In addition to the stone and soil components, CU-Structural Soil utilises a hydrogel as a non-toxic, non-phytotoxic tackifier. The structural soil process benefits from adding a tackifying agent to stabilise the mixing process. The tackifier allows for the stones and soil to mix uniformly and prevents separation of the materials resulting from vibration in transit, dumping and working of the material in installation.

CU-Structural Soil has been used in thousands of installations the United States and Canada. Similar 'structural soils' based on the same principle of a load bearing lattice with uncompacted soil in the voids has been used in many European countries and in Japan. It represents a new green technology that can acknowledge the constraints of city life while providing a place for trees.

For more information, **CLICK HERE**

Greening the inner city: How do we choose the best trees?

Nina Bassuk from the Urban Horticulture Institute, School of Integrative Plant Science Cornell University shares her thoughts on the value of green spaces in inner cities and how we should choose the best trees for this purpose

The world's population is increasingly urban. In the United States alone, 85% of the population lives in urban areas and that trend is expected to continue. If we value the green spaces and trees in our cities and parks for all the benefits they give us, we need to choose the best trees that will thrive in challenging sites.

There are four basic principles of urban tree selection:

› Trees should be pest resistant and adapted to urban environmental conditions.

› Trees should be highly diverse, including native and non-native species, but avoiding invasive species.

› Trees should meet functional and design objectives.

› Trees should match management limitations.

When we investigate these principles, it is worthwhile to delve into specifics.

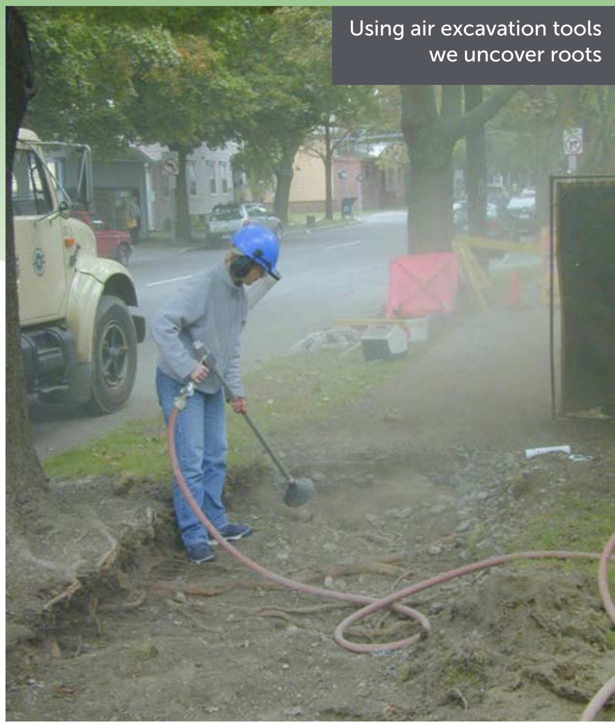
Pest resistant – adapted to environmental stress

Due to the inherently heterogeneous nature of the urban environment, tree planting sites are subject to microclimates caused by buildings and paved surfaces and the aftereffects of urban development written in the soil. On a warm sunny day when the air temperature is 24°C, the surface temperatures of pavement or building walls can reflect 40-52°C temperatures. Taken altogether, this increased heat gives rise to the urban heat island where inner cities are considerably warmer than surrounding rural areas. With increased air temperatures, trees lose water from their leaves more rapidly than a rural tree. Coupled with often-restricted planting spaces or soil that is paved over, trees experience drought stress even during what would be considered normal summer temperatures and rainfall.

With the addition of climate change, cities experience longer periods without rain and then heavy downpours. The negative effects of too much water can also be stressful for trees when air-filled pores in the soil are filled with water depriving the tree roots of needed oxygen. Above ground, trees also have to compete with utility wires, streetlights, traffic and business signage. These cause conflicts if sight lines or electricity delivery is disrupted requiring drastic pruning to squeeze the tree's canopy into the allotted space.

By far, the most stressful urban condition for trees is the lack of accessible soil. This is caused by inadvertent and purposeful soil compaction. When any new road or building is built or demolished, the soil within the area inadvertently becomes compacted due to the use of heavy machinery

Tree roots escape a confined space by growing under a sidewalk into a neighbouring lawn



Using air excavation tools we uncover roots

and moving of earth. Once compacted and crushed, it is difficult to bring back the soil so that it can support plant life. Moreover, when any pavement is laid, the soil beneath it must be purposefully compacted to bear the load of the new pavement to prevent subsiding or cracking.

Tree roots require, water, nutrients and oxygen for healthy tree growth. When soil volume is restricted these basic building blocks for tree growth can be severely restricted. Combined with reflected heat from building and pavement, poor water infiltration due to impervious surfaces, waterlogged soils that don't drain and often poor nutrient availability, it is no wonder that urban trees live a shortened life.

However, most people who enjoy a tree covered street would say that things cannot be that bad. After all many trees get big and provide many of the benefits we enjoy.

Where are the roots?

Whenever there is a large tree, there is a corresponding large, wide-spreading root system that supports that tree to supply water and nutrients.

With the use of air excavating tools, we have peeled back the soil to find where roots are growing. In many narrow, green, planting areas adjacent to roads, tree roots break out of the limited soil by exploiting the area of weakness at the interface between the sidewalk and underlying soil. When they do this, roots find accessible soil in someone's front or backyard or nearby vacant lot. Inevitably the roots of a large tree may not be where you think they are. When roots grow under pavement and increase in girth by radial growth, sidewalks may be raised causing tripping hazards, which set up a conflict between trees and municipalities.

We can select trees that are adapted or tolerant of to:

- Small planting envelopes (above and below ground) by choosing small trees;
- Heat and cold temperatures;
- Dry and wet soils;
- Poor nutrient availability and salts and;
- Insect and diseases.

Each one of these conditions is a filter reducing the potential trees that may be chosen. It is notable that the more we can reduce the stress on trees, the greater the choices we can make will be.

The one factor that no tree is adapted to is compacted soil. Compaction physically restricts root growth and prevents the acquisition of water, nutrients and oxygen. When this occurs, soil remediation must occur to engineer a more sustainable soil condition.

Highly diverse, non-invasive

I am often asked, "What is the best urban tree." There are many common street trees that are preferentially grown in cities worldwide. In the eastern United States, maples (Acer spp.) make up about 40% of the urban tree population. In Scandinavia and other parts of Europe, lindens (Tilia spp.) make up a very large percent of the urban tree population. The problem with growing just a few tried and true species is that if they become susceptible to an insect or disease (and inevitably there is always some new insect or disease!) the demise of these trees causes an enormous negative effect on the urban landscape. We have the example of Dutch Elm Disease decimating elms, Emerald Ash Borers killing all the ash trees, Asian Long Horned Beetles destroying maples and a host of other species, as well as other examples. The only true defence against pests is to plant a very diverse urban forest.

Native or non-native?

It is clear that the urban environment has been fundamentally altered by development and human habitation. The choices of trees must consider these environmental conditions and choose plants that are adapted to them.

The popular ideology promoting native species only disregards the fact that urban conditions are nothing like native conditions where many trees evolved.

The best choice is to use both native and non-native trees when they are adapted to urban site conditions. A few species have become invasive, causing economic and environmental harm, as well as harm to human health. Identifying these trees varies on a local level and should be avoided.

Trees provide ecosystem and aesthetic benefits

Increasingly we are recognising and quantifying the benefits that trees provide in the urban environment including reducing storm water runoff and pollution, providing habitat for pollinators, sequestering carbon, reducing air pollution and providing significant energy conservation in summer and winter. Tree choice affects the accrual of benefits. Trees with large canopies provide the greatest amount of energy conservation, storm water runoff reduction and carbon sequestration. A diversity of trees that flower from spring through fall will provide the greatest benefit to pollinators and other urban fauna.

What about the cost of tree management?

Many cities have quantified the benefits they receive from healthy trees. In all cases, the cost of management (preparing sites, choosing good trees and providing reasonable aftercare) is far outweighed by the ecosystem benefits that are gained.

We take trees for granted. Only when many trees are removed do people realise the difference trees make in their lives. Continued research focusing on better tree selection for challenging urban sites will provide long-term benefits that we can all enjoy.

The limits of tree selection

But there are limits to the benefits of proper plant selection. With knowledge and experience you can choose a tree that is tolerant of temperature extremes, insect and disease infestation, alkaline soil, wet, poorly draining soil and drought. You can choose a tree that fits into the restrictions of the urban landscape including overhead utility wires, signage and lights and narrow tree planting spaces near roads and traffic. However, you cannot choose a tree that will grow in severely compacted soil, often found as a result of commercial and municipal development. In this case, the best tree in the world will grow poorly when soil conditions are poor.

No tree will thrive without adequate room to grow, nor will they survive for long in compacted soils. An example often cited by horticulturists is the 'bath tub effect', whereby trees are planted in compacted soils that can't drain water and their roots, unseen to the human eye, drown or rot. 'Compaction is probably the single most limiting soil condition for urban plants,' explains Dr Bassuk.

Soil can be a scarce commodity in the urban environment. Underpinning all soil remediation techniques is the need to know how much good soil a tree needs to grow into its envisioned mature size. Dr Bassuk and colleagues developed a method for determining an adequate volume of soil based on tree canopy size, the climate at the planting site (e.g. how hot, dry and windy it is likely to be during the hottest time of the year), how much water the soil holds, how much rainfall or irrigation can be expected and how much under-planting there is including turfgrass. By plugging in data from meteorological records, soil and envisioned tree canopy, a reasonable estimate of adequate soil for healthy tree growth can be determined.

'Finding' enough soil in the urban environment

To prevent the effects of soil compaction under pavements, Dr Bassuk and her colleagues have developed a patented system known as CU-Structural Soil® or CU-Soil®, a precise mixture of soil and gravel that is specifically designed to go under sidewalks and pavement. The engineered soil allows for the compaction required to bear heavy loads, but at the same time has large pores that allow for tree roots to grow through it. In 20 years this urban soil has been installed in approximately 2000 locations in almost all of the United States, Canada, Puerto Rico, Ireland and the UK. Even better, by combining porous pavement systems and CU-Soil, it can act as an underground reservoir for storm water including polluted parking lot runoff. While the structural soil stores, filters and cleanses the runoff, tree roots take it up and cool the hot urban pavement below. In doing so CU-Soil helps to reduce stormwater runoff, and cools the urban heat island.

They have also developed another technique known by the playful name of 'Scoop and Dump'. In this system, they use a backhoe to dig in 'veins' of rich compost into poor, compacted soils. 'The backhoe scoops compost and compacted soil down to a depth of 18 inches and dumps it back on the ground, thus fracturing the compacted soil and allowing compost to settle between the clods,' explains Dr Bassuk. 'Plants are planted and mulched. The mulch is reapplied annually until there is canopy closure to replenish the organic matter in the soil. This technique has affected long-term soil remediation and improved plant growth.'

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