PART ONE

1

Designing Spaces for Trees

This first chapter sums up all the components in understanding a site, developing a design, and constructing a landscape that incorporates large, healthy trees. It provides a series of principles that serve as a framework for learning the science and techniques presented in the remaining chapters. Let's start underground, in the areas too often overlooked.

UNDERSTANDING NATIVE SOIL

To design spaces for trees, a designer must first understand soil. This does not mean becoming a soil scientist, but the designer needs to have a basic understanding of the existing soil at the site and what soil improvements are needed to attain the desired results. In large or complex landscapes, the design team may want to hire a soil

Figure 1.1.1. Trees survive in difficult places, but success needs to be more certain in the densest parts of cities.

consultant, but for most projects, the designer must have enough skill to evaluate the soil and make decisions based on a reasonable level of knowledge.

A designer also needs a thorough understanding of the biology of trees. Together, these two sets of information provide a basis for determining sizes of soil areas and predicting the response of trees to available conditions.

The following five principles of soil science are vital to successfully evaluating soil resources and designing with soil.

Soil Physical Properties

How did the soil get there? What is it made of? How coarse or fine is it? How are the particles arranged? Are the particles glued together to form a larger mass? Finally, how tightly are the particles compacted?

Soil Biological Properties

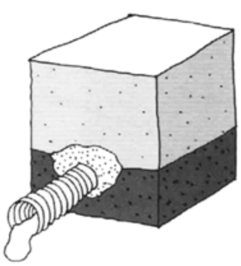
What is the organic content of the soil? Is there a viable, living set of organisms such as fungi, bacteria, insects, and worms? Are leaves left on the ground to provide a food source for these organisms?

Soil Chemistry

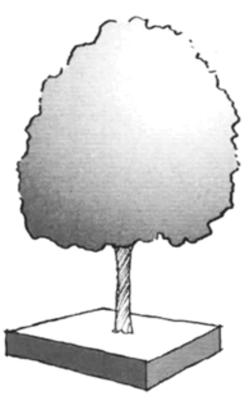
Are there sufficient chemical elements to sustain trees and support soil biology? What is the soil's pH? Are there chemicals in the soil that are toxic to trees, soil organisms, or animals?

Soil Drainage

How well does the soil drain? Is this a function of its physical properties, biological properties, topography, underlying or adjacent conditions, or a combination of several factors?



These first four soil principles are interrelated. A change in one might trigger a change in the others. The designer must understand what exists and how it may change or be changed during the development process. There are many ways to correct deficiencies during the early part of the design process. However, good soils are quite fragile and can easily be degraded if not given priority in the design process and protected during construction. The simple act of moving good topsoil from one place to another can seriously degrade its quality.



Soil Volume

Soil volume is the principle that links issues of soil quality and tree growth. In urban areas, there is intense competition for space. Buildings, underground utilities, and large areas of paving for vehicles and pedestrians consume much of the urban landscape and squeeze the zones where tree roots can grow. Yet tree growth is directly related to the volume of soil available for root growth. Small soil volumes result in small trees, no matter the species.

For this reason, soil volume requirements must be factored into the many compromises that represent the urban design process. This process determines space and budgets for roads, sidewalks, utilities, grading, stormwater systems—and trees.

Designers can easily look up the minimum soil volumes required to sustain trees of different sizes in the urban landscape. Soil volume calculations must be made during the earliest phases of the design process, and must have equal standing with the determination of the sizes of pipes or the turning radius of automobiles.

UNDERSTANDING URBAN SOIL

Urban Soils Are Highly Disturbed

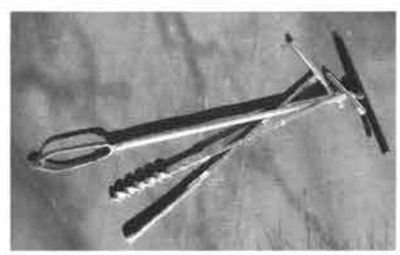
Human activity changes soil. Urban areas have more human activity, and thus more disturbed soil. This is not a recent problem. It began centuries ago (depending where you are) with the removal of the first trees and the start of agricultural activity. Each overlay of activity further alters the soil.

In many places, there may have been four or more soil disturbance cycles on each piece of land over the last 200 or more years. These might include a tree removal cycle, an agricultural cycle, and at least two different building cycles. Some soils, particularly coarse, sandy soils in the southeast coastal United States or the glacial outwash soils of New England, can better handle repeated soil disturbance than silt or clay loam soils often found in floodplains or uplifted ocean bottoms.

The more times and greater distance the soil has been physically moved, the more likely it will become degraded. As different soils are layered over previous disturbances, or include building material, they degrade even further. Toxic material may harm the soil's ability to support roots.

Some soil disturbance can be beneficial. Old rubble building foundations or the loose backfill over utility lines may provide good rooting opportunities. However, it is difficult to predict when they will be good places for roots to grow.

Undertake an Urban Soil Assessment



In natural spaces, analyzing the site's geologic and weather history makes it possible to reasonably predict soil conditions. Urban soil is the result of random disturbance, subject to the whims of human need, and its quality is much more difficult to predict.

An important first step in a design approach to an urban space is to determine the number of soil disturbances and when they occurred. Within the profession of landscape architecture it is well accepted, even required, to undertake a thorough analysis of soil and water conditions at a site where existing soil conditions are "natural" before the start of the design process. In urban sites with highly disturbed soils, this preliminary research is almost never done unless a significant amount of toxic material is anticipated. The analysis process at an urban site, especially a paved site, is difficult, less precise, and therefore ignored. Yet it is precisely in these tough conditions where additional information can pay the biggest dividends by reducing development cost and environmental impacts.

Assessing urban soil requires a thorough understanding of the human history of the site. Information on development history can come from old maps, planning documents, tax records, and photographs. A small amount of time at the local planning office, historical society, and library can unearth great quantities of useful data.

A thorough field assessment can yield a second layer of information. Each plant has critical growing requirements that reveal the soil conditions. Studying any plants, including weeds growing in cracks in the paving, and examining the type and condition of existing trees in the area will reveal information on soil type, drainage, and compaction level.

Finally, look at any excavations that may be open and take soil samples using a soil probe at any opportunity where the soil is accessible.

Use the Soil Information

The soil assessment will identify areas of usable and unusable soil and good or poor drainage. Wherever possible, designers should incorporate usable soil resources into their plans. It may be necessary to safeguard these areas in the same way the soil around an existing tree would be protected. In fact, it is the same thing, except in this case the rooting area is being set aside for a future tree.

As the intensity of land use increases, there may be no usable soil resources remaining after construction. However, there still may be opportunities to recycle mineral soil on the site. Using this material is more sustainable than removing it and importing new soil from another site. Often, the only actions needed to make urban soil usable are the elimination of compacted layers and the addition of organic components. Recycling can only occur if the site designer understands the composition and location of existing soil types.

UNDERSTANDING TREE BIOLOGY

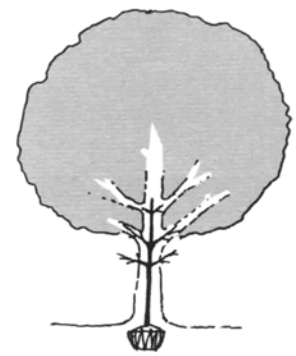
Trees are living, growing organisms. This may seem obvious, but one would never know it to look at the trees in many of the urban streetscape and plaza designs built in the last half of the 20th century. Trees look like they were intended as small sculptures or decorations, and are regularly replaced as part of normal maintenance. They may never become large enough to provide shade, cool the space, retain stormwater, or otherwise improve the environment.

In the worst cases, urban trees go through a prolonged and unsightly decline and then are not replaced, leaving a bleak monument to the failure of the design and those who funded the project. In other places, trees have been able to find unintended rooting environments, often within the pavement systems. Here the tree survives, but tears apart the walking surfaces, making the landscape dangerous to traverse. Entire plazas have been closed and rebuilt as a result of designs that did not respect basic tree biology and physics. Understanding a few basic principles of tree biology and physics during the design period can make a huge improvement in the long-term success of the trees.

The following seven principles define the most important areas of tree biology to be understood when designing spaces for trees.

Figure 1.1.2. Lack of understanding of the relationship between tree biology and urban soil often results in either dead trees or dead sidewalks.

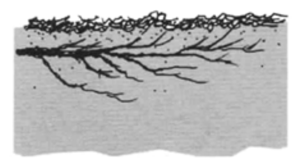
Trees Grow



The most basic principle of tree biology is that the entire tree system must grow and become larger each year in order to survive. Branches must continually get longer, trunks thicker, trunk bases more swollen, and root systems increasingly larger and more complex. Any design that ignores this principle will fail when the tree bumps into a restraint. Anything that is placed around the tree—a string to secure burlap, a band to hold a light, a tree grate or tree guard—will, if not removed, strangle the tree or branch.

Nature regulates the ultimate size the tree can attain, but urban trees die long before they reach their natural limitations. The Japanese art of bonsai demonstrates that tree growth rates can be artificially reduced to low levels with enough maintenance and constant care. Many bonsai techniques, including root pruning, would be impossible to perform on a full-size tree, while the required frequency and continuity of maintenance is well beyond most tree management budgets. Chemical growth regulators show some promise for slowing tree growth, but the impact of long-term use in urban soils is not well understood, and finding ways to grow long lived small trees is counter to the environmental goals of planting trees.

Leaf-to-Root Balance



Trees, like all plants, must maintain a balance between the surface area of the tree that can photosynthesize (mostly the leaf area) and the surface area of the tree that can take up water and chemicals (its absorbing roots). When one part of the system gets out of balance, hormonal regulators within the tree adjust the other.

If the trees roots are cut, damaged, or have no more room to grow, branches die, twigs do not grow as long, and the tree produces smaller and/or fewer leaves. If branches are removed or die, tree roots will die or fail to grow the following year. This balancing act leaves many telltale signs, such as smaller leaves, fewer buds, and shorter branch extensions. Arborists use these indicators to help determine the health of a tree. This principle may be applied to extend the life of a tree in a confined space by constantly pruning branches and following established pleaching or pollarding practices. Europeans have been successful at this technique on a limited number of species, but the process requires a trained arborist to work continuously on a given tree population. The level of effort needed to achieve success is far beyond that provided to trees in typical American cities.

Horizontal Roots

To survive, tree roots need oxygen and water, both found in the upper layers of the soil. Tree roots often grow directly under pavement in a thin layer of soil so as to get the best balance of water and air. Tree roots can grow much faster than branches, and have been measured at up to 10 feet or more per year. The need for oxygen and the rapid growth of roots mean that a tree's root system is often horizontal in structure and will cover far more territory than its crown. The extended roots will intertwine with the roots of adjacent trees.

The depth of this horizontal system is limited by the degree of transfer of oxygen and carbon dioxide between the air and the soil. This may be as little as a few inches to many feet depending on soil type, drainage, and compaction. Deep roots can be found in cities and shallow roots are not limited to urban soils. Old building foundations and soils disturbed by the installation of utility lines can create opportunities for urban trees to find deep rooting space. A buried sheet of asphalt, a perched water table, or a buried compaction layer can confine roots to a thin upper layer of soil.

Aggressive, Opportunistic Roots

Roots tend to be aggressive and opportunistic in finding and exploiting resources. They create complex, dense mats in favorable conditions and long, less dense systems in poorer conditions. Roots also tend to grow in the most favorable environment available. One tree might grow only a few roots in a poor soil if better opportunities are available, while the same species of tree might grow many roots in the identical poor soil, if it is the best one within reach.

Tree roots can exert great force on objects. If a root grows under or beside an object and later finds an area of good growing conditions, the expansion of that root can move or break objects of great weight or strength. These root qualities cause damage to paving, curbs, and walls if not understood.

Fragile Roots and Strong Roots

When preserving existing trees or preparing sites for new trees, it is important to consider all the factors that can damage tree roots. While roots can be aggressive and opportunistic, the smallest roots, those that start the growth process and take up water and nutrients, are quite fragile and short-lived. They are easily killed by soil compaction, cutting, too much water, too little water, extremes of heat and cold, and many chemicals that are toxic to plants, including chemicals produced by other plants.

The larger roots, bigger than an inch, that connect the fine roots to the trunk are stronger. With the exception of mechanical damage that breaks the bark, they are much less susceptible to the types of impacts that damage smaller roots. Often, reduction in soil compaction is used as a justification for installing tree grates in urban areas. However, the large structural roots that grow immediately out of the trunk are not as vulnerable to soil compaction. Instead of protecting the tree, the grate often damages it as the metal collar girdles the expanding trunk.

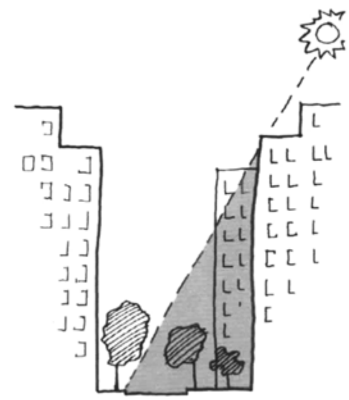
Dynamic Structure

A tree's structure is conceptually a vertical cantilever, which resists the dynamic forces of wind and gravity in the crown. The root plate anchors the trunk, which is cantilevered from this horizontal structure. To accomplish this, the tree depends on a strong joint between the trunk and the roots. As the tree grows larger, the dynamic forces of its movement stress this joint and the tree responds by adding more wood at its base. This produces a pronounced swelling called the trunk flare. Large trees lacking this flare usually have some restriction at or below the ground, were planted too deeply or had fill placed around the trunk. Over time this buried joint may become rotten, and the tree may decline or simply fall over.

One avoidable cause of this weakness is paving directly around the base of a young tree. Designers should be required to plan for and draw a mature tree with a full trunk flare in the proposed planting hole, to demonstrate that the design will function when the tree becomes large.

The principle of dynamic structure applies to other joints in the tree. Branch unions can become weak if the tree is not pruned properly, leaving branches with tight angles. Roots that are damaged or cut can cause the tree to fall over. Trees that grow more branches on one side due to the shade of a competing tree or building may become unstable.

Light



Existing tree canopy and tall buildings often limit the natural light that trees need to grow. Only certain species can tolerate the low direct-light levels available in deep, canyon-like urban spaces. This principle also comes into play when trying to establish new tree plantings among large existing trees. In low light, use climax species of trees that can grow under existing forest canopies.

If you are familiar with tree biology, you will note that the principles listed here do not mention most of the detailed parts of a tree, such as cambium, xylem, and phloem. In this overview of tree biology, we need consider only the issues that affect the success of the tree and that can be controlled during its design, installation, and maintenance.

UP BY ROOTS—DESIGN PRINCIPLES

Once the designer understands the environment of the site and the requirements of the trees, this information can inform and inspire a suitable design approach. Trees need more space at the soil line and below the ground than is allotted in most contemporary urban design. There is fierce competition for this space, and for the budget needed to prepare this space for trees.

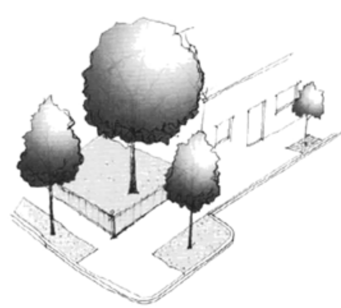
To ensure that each tree gets its needed share of space and budget, the designer must defend tree requirements from the beginning of design through the end of construction. Designing space for trees cannot be left to the construction document phase. Successful tree design cannot be an afterthought once the design direction is set.

The following ten principles can guide the process of building landscapes from initial concept sketches through construction and the start of maintenance cycles. The principles are organized into soil-based strategies, tree-based strategies, and management-based strategies.

Soil-Based Strategies

Soil-based strategies work with existing soil resources, protect and improve those resources, and recognize when to abandon the existing soil in favor of replacements.

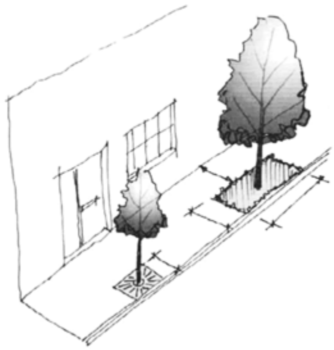
Principle 1. Plant the Easy Places First



It sounds simple, doesn't it? Assign large trees to areas where you have the largest or the best soil resources.

In the urban environment, there are always easier and more difficult places to grow trees. Big differences in growth possibilities may be only a few yards apart, a result of slight variations in a design decision or changes in soil or drainage patterns. These sometimes subtle differences may be identified in the site assessment or perceived by an experienced designer who understands trees and their needs. Starting the design with the easier locations yields a greater chance of successful trees at a lower price. This may mean other goals have to be compromised, but all designs involve balance among conflicting goals.

Working with existing resources is also fundamental to the principles of environmentally sustainable design. One of the best examples of this principle is the decision to place street trees between the sidewalk and the curb, as opposed to placing them between the sidewalk and the building. The soil between the walk and the building is often more suitable to grow a healthy large tree, but it is rare for this location to be selected. Conversely, the space between the curb and the walk is usually too small and the soil too compacted for a large tree. The curbside location may be preferred for aesthetic and urban design reasons. Yet unless the project has the resources to overcome the technical problems of putting trees in very confined space, these advantages may be beside the point. There is no aesthetic value to a dead tree or an empty planting hole.



Principle 2. Make Larger Planting Spaces

Another simple way to improve the health of trees in urban areas is to reduce the areas of paving and increase the areas open for soil. Of all the principles, this is the most important and the easiest to undertake. Competition for space in the city is severe, but rarely does anyone ask, "Could the paving be reduced even slightly to improve tree growth?" This is because designers who are not interested in the health of trees often make paving decisions.

Architects, civil engineers, and many landscape architects see paving as the primary element in the design. They either do not know how their decisions affect tree health or may shrug these concerns off in the belief that trees can be replaced when they die. Paving is considered easy to maintain and is necessary for pedestrian and vehicle traffic. The size of a paved area may also be part of an aesthetic plan. Yet it is possible to ask how wide roads and sidewalks have to be, and how much paving is really needed for a plaza.

Fewer larger spaces for clustered trees are better than many smaller isolated tree plantings. Often a small change in the widths of drives, walks, and spaces between obstructions can result in enormous benefits to the amount of soil available to the tree, increasing tree longevity.

Formulas for determining the amount of soil needed to support a large tree are provided in this book. Use them to gain support for larger soil areas.

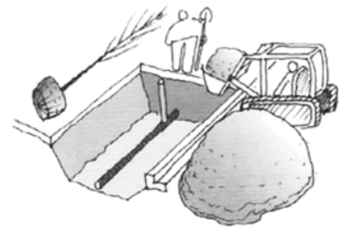
Principle 3. Preserve and Reuse Existing Soil Resources

Despite dire predictions of destroyed soils and poor growing conditions, there are often usable soils at urban sites. If these soils can be identified, incorporated into the design and protected during the construction, a small piece of the environment has been preserved. It is hard to make good soil, so anytime reasonable soil exists, reuse is the best option.

Removing and replacing soil is a very environmentally destructive act. Existing soil must be moved at great expense and use of fuel, and often ends up as fill dirt or, worse, in a landfill. The harvesting of topsoil and other materials to make replacement soil results in large areas of degraded land, silting of waterways, and again considerable use of fuel. If promoters and stakeholders wish to represent a project as sustainable, then preserving, protecting, and reusing existing soil must be a priority. Even without this concern, a simple budget calculation can make a strong case for reuse.

Soil reuse, protection, and preservation are not easy tasks in a complex construction process. They demand the same level of effort as tree preservation, and many of the principles are the same. Think of soil preservation as growing space for future trees. Reusing soil—moving it around the site and restoring it in a new location—is the second-best option, but comes with its own requirements and an acceptance of a significant level of soil degradation no matter how carefully it is handled.

Principle 4. Improve Soil and Drainage



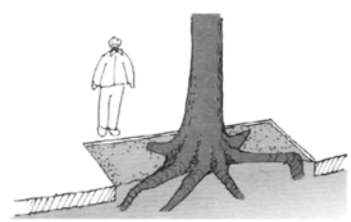
Once the design has established the limit of available soil area, make this soil "right for the tree." Sometimes simple deep tilling of compacted soil is sufficient, while in other places complete soil replacement is required. Knowledge of soils, drainage, and the requirements of the trees to be planted is necessary to make the right decisions. In some cases, a little soil amendment can actually create more problems by forming "bathtubs" that hold water. Improper soil amendments are one of the most common mistakes in working with soil, and much of this book is devoted to this subject.

Too much water creates more problems in the urban landscape than too little. Plants can adapt to dry conditions, and a little supplemental water at establishment or during a drought can make all the difference. In contrast, drainage problems can be difficult to fix, especially if not discovered until after the project is finished. Poor drainage will undo all the other principles.

Tree-Based Strategies

Tree-based strategies discuss the needs of the tree and instruct the designer on how they are accommodated into the design.

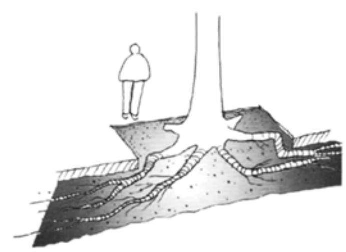
Principle 5. Respect the Base of the Tree



Do not pave within the area of the tree's future trunk flare. The mature trunk flare is the pronounced swelling at the base of the tree just before the trunk disappears underground. It is usually more than twice the diameter of the trunk at 4 feet above the ground. This area must be treated with great care and respect. The trunk will expand to dimensions dictated by the tree, not the designer. The tree will either push aside any constrictions or suffer damage from them.

Just beyond the trunk flare, the first set of large roots extends out underground and rapidly tapers away from the trunk over the next 6 to 8 feet. These are the roots that cause the most conflict with paving and curbs. Obstructions within this area are always at risk unless measures are taken to prevent root intrusion or develop conditions that allow roots to grow deeper within the soil.

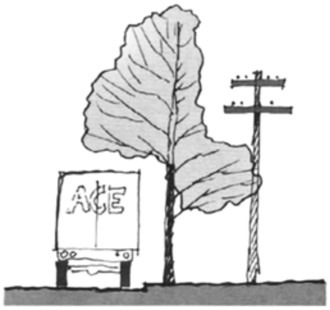
Principle 6. Make Space for Roots



Design spaces for roots under the pavement and adopt different approaches to root space design as conditions change.

At some point in the design process, it may simply be impossible to provide sufficient soil for the tree in an area separate from the paved areas. At that point the designer must begin to anticipate roots growing under the pavement. This may limit the type of paving that can be used and may increase the cost of the project. Yet it is possible to encourage root growth under pavement in ways that do not impact the stability of the pavement.

In urban areas, when the rooting space is smaller than required by the tree, uniform design and detailing of the tree rooting space often does not result in uniform tree growth. Trees will adapt to subtle differences in the area around the prepared rooting space. Designers must consider each tree as a unique organism in a unique environment and develop solutions that reflect these differences in conditions. This book offers many approaches to solve soil and drainage problems. Use as many of them as are appropriate to optimize the budget with a goal of growing large, healthy trees.



Principle 7. Select the Right Tree

Put the right tree in the right place and make the place right for the tree.

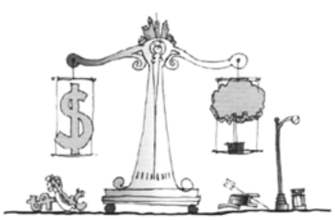
Only after all the above principles have been followed can the design consider tree selection. Selecting the right tree assumes that one has made every effort to make the place right for the tree.This order of priority gives the designer a much wider range of available trees from which to choose. Select trees primarily for their ability to perform the desired functions and aesthetic contributions to the design. Even pines can be used as street trees, if their use would meet the goals of the project.

Selecting the right tree also assumes a high level of professional knowledge about the requirements of each tree. Designers must still take on the responsibility of learning the nuances of horticulture. This is more than a quick look at a textbook resource or the use of a digital plant selection program.Those resources are great beginning points, but are no substitute for personal experience. Local climate, maintenance, nursery availability, regional soil differences, and other variables must become part of the designer's thought process.

Once the tree is chosen, go back through the design process and make sure the site has been made right for that tree. Be prepared to change elements if a tree selection changes.

Management-Based Strategies

Management-based strategies provide tools to fund and implement the first two sets of strategies.



Principle 8. Establish Reasonable Tree and Soil Budgets

Balance the design quality of all elements in the landscape.

Trees are just one element in the urban fabric needed to support design goals of bringing people together in dense yet attractive spaces for economic and social interaction. Other elements, such as paving, furnishings, and lighting, are also important. It is necessary to keep the resources devoted to each element balanced within the available budget.

Growing and maintaining a large, healthy tree in urban soils requires about the same resources per unit as installing and maintaining a good-quality street light. Trees and lights offer different benefits to the community, but these benefits are reasonably similar in value. Too many landscapes are built with high-quality light fixtures, paving, and furniture placed among dead or stressed trees because the designer did not understand the need to balance project resources.

As budgets run up against limits, adjust the quality or quantity of everything a little bit. Planting fewer trees, but providing each with healthy soil, will be a better investment and produce a better landscape over the long term.

Principle 9. Create Detailed Tree and Soil Construction Documents

Once the concept design has been developed with the basic systems needed to support trees, the construction document process must continue with the same high level of care and commitment to the principles of soil science and tree biology. As in any construction system, there is a big leap from the planting concept plan to the finished product.

Make detailed drawings of the soil design. A separate soil and drainage installation plan should be a requirement. Draw the trees in sections to scale, accurately depicting the root ball size. Make sure that each tree fits in the allotted space at the time of construction and that the mature root system will fit in the space in 30 or 40 years. Draw the predicted mature root system, at least during the detail development period, to test the suitability of details.

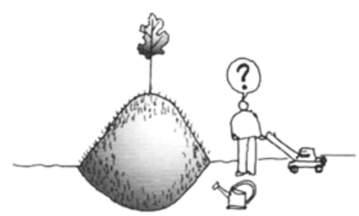
How does water move into and out of the soil? Can the contractor actually place the soil in the locations and in the sequences of other construction? It should be an embarrassment to design professions how often they fail at these basic documentation tasks. Project documentation that relies on standard details or specifications will invariably fail when the conditions are not "typical." It is the designer's job to look at all the conditions and develop solutions for each variation from the mythical norm.

Even the best set of documents cannot succeed without cooperation and coordination between designer and contractor. It is the designer's job to ensure that the contractor follows document requirements. Soils and plants are highly variable commodities, and there is always a wide range of possible interpretations of specifications.

Inspect materials frequently, starting at their source and continuing during the construction process as needed to ensure quality. The problem of root balls with overly deep roots or circling roots must be corrected in the nursery, not at the job site. Test and review soil to ensure that it supports the plants selected and is compatible with the drainage assumptions.

Review drainage systems, subgrade conditions, soil installation, soil compaction, and root balls throughout the construction process. The same tool the designer used to assess the soil at the beginning of the project, a soil probe, is useful when reviewing landscape installations, allowing inspection of root ball, soil quality, drainage performance, and soil compaction. The designer must have the scientific knowledge to interpret what is observed.

Principle 10. Design for Maintenance



Urban environments depend on maintenance. In intensely used urban settings, the concept of low maintenance is not a practical reality. During the design process, identify the source and capability of that maintenance, and be sure that the maintenance team is informed of specialized requirements and system designs.

A properly designed landscape should be able to support trees with minimum maintenance. If the tree fails because the level of maintenance available could not provide for its minimum requirements, is the design at fault? Understanding the maintenance capabilities of the client should be a fundamental design criterion.

Many projects that receive wide acclaim for design success have small armies of maintenance staff who can overcome soil design flaws. When another designer tries to emulate these award-winning projects without the same level of maintenance, plant failure is almost ensured. Sometimes, particularly in cases of poor drainage, the design is simply not maintainable. Design choices do affect the ability to maintain the design.

Maintenance providers, like designers, must understand soil and tree biology. How soil and trees are treated during maintenance is as crucial as it was during construction.

For example, few people, including landscape maintenance contractors, know that plants look wilted from being either over- or underwatered. Lots of hard work can be undone by overwatering the soil during the first summer after the project is built. Well-developed soil biology can be severely damaged by chemical applications intended to improve plant health. Soil testing, including monitoring of soil biology, should be a regular part of the maintenance process, and soil lab reports should be consulted before deciding on any chemical application.

Pruning must be done with the long-term growth goals for the tree and to set up proper branching patterns for the creation of strong branch joints.

While the primary designers are rarely part of the ongoing maintenance team they must set the landscape on an attainable maintenance course and make strong recommendations to influence quality maintenance practices by certified arborists and other providers.

FURTHER STUDY REQUIRED

These ten principles are not intended to provide definitive answers to the challenge of designing spaces for trees in urban spaces. They are general guidelines that require further study of the science of trees and soils. In the following chapters, we'll go into more detail about applying these guidelines.