URBAN FORESTRY

A Manual for the State Forestry Agencies in the Southern Region

Unit: Urban Soils

The Urban Forestry Manual is being developed by the USDA Forest Service, Southern Region and Southern Research Station, and the Southern Group of State Foresters as an educational tool for State forestry agency employees and others who work with communities on urban forestry. It can be used for self-guided learning, finding specific information on a topic and developing workshops and presentations. There are 16 units (chapters) in the Manual - at this time 9 units are on the web site (www.urbanforestrysouth.usda.gov). The other units will be added as they become available.

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Using this Manual

The Urban Forestry Manual provides the scientific, technical, and practical information needed to work with communities on urban forestry. There are 16 units (listed below) that address specific topics in the practice of urban forestry. These units have been developed as a series, each building upon the information in previous ones. The units may also be used individually to gain information about a specific topic.

Benefits and Costs of the Urban Forest is the first unit in the Urban Forestry Manual. This is an introduction to urban forestry and it explains why your work with communities and individuals in urban forestry is important. This unit also includes information about how to maximize the benefits and minimize the costs related to the urban forest.

The Role of the State Forestry Agency in Urban Forestry is an introduction to State forestry agencies' responsibilities and activities in urban forestry. It explains why partnerships are important to State forestry agencies activities in urban forestry. This unit also discusses the importance of working with communities and individuals.

Tree Biology is an introduction to how trees grow and live. It describes how trees are structured, how they function, and how they grow and develop. It also explains how the urban environment influences tree growth and development.

Dendrology is an introduction to identifying and understanding trees in the urban environment. It explains the classification of trees, naming trees and tree identification. This unit also includes information on how characteristics of the urban environment influence tree identification.

Urban Soils is an introduction to the role that soils play in the health of the urban forest. It explains what soil characteristics are important for healthy tree growth. This unit also includes information about common soil problems in urban areas.

Site and Tree Selection provides information on how to select a site and species to maximize the benefits and minimize the costs related to urban forestry. It explains what factors you need to consider when selecting a planting site, tree species, and tree stock. This unit also discusses how to match these factors to ensure healthy tree growth and development.

Tree Planting is a unit that will introduces factors to consider and techniques to implement when planting trees. It includes recommended guidelines for planting and post-planting. It also explains how to work with communities and individuals to successfully plant trees.

Tree Maintenance is an introduction to the importance of providing regular maintenance to the urban forest. The basic steps to preventative maintenance are discussed, such as fertilization, mulching, pruning and tree protection.

Tree Diagnosis and Treatment provides an introduction on how to diagnosis and treat tree health problems. This unit explains how your knowledge and application of diagnosis and treatment can improve the health of the urban forest. It also includes information on why it is important to prevent tree health problems.

Trees and Construction is an introduction to the relationship between construction activities and trees. It explains the importance of communication during the construction process. The focus is on the impact of construction activities on trees, the protection of trees during construction, and care for the tree before and after construction.

Hazard Trees is an introduction to the importance of recognizing a hazard tree. It gives a general overview on evaluating a target, site conditions and the tree. This unit also includes information on how to prevent and manage hazard trees.

Urban Wildlife is an introduction to the relationship between wildlife and the urban environment. It first defines urban wildlife and describes the needs of wildlife, such as food, water, cover and living space. Then it discusses wildlife habitat in urban areas and how wildlife adapts to urban habitat. It also includes information on how to encourage and discourage wildlife.

Urban Ecosystems is an introduction to the role that trees play within an urban ecosystem. It first defines an ecosystem and why it is important to understand ecosystems. Then is discusses ecological concepts, such as structure and function, that are important to understanding ecosystems. This unit also includes information on understanding challenges in the urban forest ecosystem.

Urban Forestry Planning and Management is an introduction to the importance of planning and managing the urban forest. It starts with a definition of an urban forest management plan and why they are important. Then it discusses the steps involved in developing a management plan. It also includes information on the different components in a management plan.

Urban Forestry and Public Policy is an introduction to understanding public policy and how it relates to urban forestry. It first describes the role that each level of government has in setting public policy related to urban forestry. Next it provides information on local government in more detail because this is where most urban forestry policy is created and implemented. The role that Tree Boards have with local government is also discussed. The final section reviews public policy tools that can be used to address urban forestry issues in a community.

Working with the Public is an introduction on how to effectively work with the public. It starts with tips on how to work together as a team and how to work with volunteers. Then it discusses the role of communication and education in working with the public. The unit also includes information on the importance of leadership in urban forestry.

Using Each Unit

Each unit in the Urban Forestry Manual is organized as follows:

Table of Contents
Lists major topics that are included in the unit.

Unit Overview
Presents goals and objectives for the unit.

Before You Begin
Consider how your current activities and experiences relate to this topic.

Content
Presents specific material about this subject under several headings.

Next?
Think about how you can use the information in your daily responsibilities and in developing your career in forestry.

For More Information
Lists other sources of information about this subject, as well as the literature cited in the unit.

Appendix
Some units have an appendix that may include checklists or other information.

In addition, each unit has two sections that will help you assess your learning of the information.

Checking Your Understanding
At the end of major sections in the unit, there are short-answer questions about the information you have read. After you have written the answers, you may compare your responses to the answers provided at the end of each unit.

Case Study
These are stories based on the real experiences. The questions at the end of the case study challenge you to use the information you learned to solve a problem similar to what you will be facing when working. You will be asked to analyze an actual urban forestry problem and prepare your solutions. There are no right or wrong answers -- only what you decide is the best course of action after considering all of the information.

Urban Soils

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Overview

Soil conditions greatly influence the growth and vigor of trees. Soil provides trees with water, oxygen, nutrients, and support for the root system. Roots need a healthy soil environment to grow in, and strong root development directly influences the growth of the above-ground parts of the tree. This unit begins with a definition of soil and descriptions of ways to identify soil composition. Next, the characteristics of soil essential for healthy tree growth are discussed. The last section reviews common problems found in urban soils and suggests techniques to prevent or correct them.

"Cooties!"

Will the Twain Ever Meet?

The State forestry agency had recently purchased a new refrigerated truck for transporting seedlings from the nurseries to locations around the State. Steve, the Urban Forestry Program Coordinator, was the first to use the truck when he took a truckload of red maple seedlings to a local, non-profit organization for a community tree planting. The next week Andy, a County Forester, was getting ready to take a truckload of seedlings to a reforestation project in the eastern part of the State. Soon he was back, teasing Steve, "The new truck is ruined! How can I possibly drive a truck that has been contaminated with urban dirt? The truck needs to be fumigated immediately!" Steve just smiled and said, "You never know. That urban soil might do the rural trees some good."

O land and soil, red soil and sweet-gum tree, so scant of grass, so profligate of pines.
Jean Toomer (1894-1967), Song of the Son, st. 2

Before You Begin

Soils perform a critical but often overlooked role in the growth and development of trees. This unit discusses many of the soil characteristics necessary for tree growth and examines specific soil conditions found in urban areas. Before beginning this unit, think about your own experiences with the different types of soil conditions you have found in your community.

- Describe some of the soil conditions that you have found when planting trees in various locations in your community.

- When working in your local area, have you found tree health problems that were directly related to the soil conditions? What types of problems have you identified?

- How do you think an understanding of urban soil conditions will help you when working with homeowners and local groups in your community?

Think about how information on urban soil conditions will help you in your job and use another page to write down some of your thoughts.

What Is Soil?

Soils are complex systems of solid matter, pore spaces filled with water and oxygen, and numerous bacteria, fungi, and other organisms (Harris 1992). Soils are also dynamic, constantly changing through interaction with other features of the environment. Soil is a mixture of four basic components:

- Inorganic materials (minerals), including rock, clay, silt, and sand, give structure to the soil.
- Organic matter, including living and decomposing organisms and plant parts, supplies nutrients and helps hold moisture in the soil.
- Air that moves through the pore spaces provides oxygen to the roots.
- Water and dissolved nutrients, important for a number of the tree's life processes, also move through the pore spaces.

A soil composed of 45% inorganic materials, 5% organic matter, 25% air and 25% water by volume is often said to be an ideal mix. This is the best mix for young trees, but soil requirements do vary by tree species. Soils that have been structurally or chemically altered by construction and other activities may not have the four components in the amounts needed for healthy soil.

Benefits of knowing about soils
Proper soil management is necessary for a healthy urban forest. There are many ways the information in this unit can be used to provide assistance (table 1).

Table 1. Examples of ways to use soil information when providing assistance and potential recipients.

<table>
<tr><th>Technical/Educational Assistance</th><th>Planning Assistance</th><th>Potential Recipients</th></tr>
<tr><td>• Site selection
• Tree selection
• Planting requirements
• Tree maintenance
• Diagnosis and treatment
• Hazardous-tree identification
• Soil erosion control</td><td>• Land management plans
• Construction site plans
• Erosion control plans
• Water quality management
• Recreation site management</td><td>• Local government
• Land development companies
• Engineers
• Architects
• Homeowners
• Landowners</td></tr>
</table>

How is Soil Formed?

Soil is the surface layer of the earth in which plants grow. Below this surface is a layer of bedrock that is weathered by the environment over long periods of time, forming the parent material of the soil. Weather and small plants and animals continue to break down the parent material into smaller and smaller particles. Combined with organic matter, air, and water, these particles of parent material form soil. Soils differ greatly in composition and structure because of the physical processes involved in their formation at each location (tables 2 and 3).

Table 2. Physical factors that influence soil formation

Physical Factors	Description
Parent material	The parent material of soil can be weathered rock, volcanic ash, or sediments deposited by wind, water, or glaciers. Most soil characteristics are based on the geology of this parent material. Types of parent material include igneous, metamorphic, and sedimentary bedrock.
Climate	Water, temperature, and wind all contribute to soil formation by influencing the rate of weathering, mineral and element transport, and type and number of living organisms found in the soil.
Living organisms	Plants and animals add organic matter to the soil, physically altering its structure.
Landscape position	The location of a site in the landscape, such as the slope of a hill or bottom of a valley, influences soil formation. For example, during a rainstorm a hillside can lose soil and minerals to a lower elevation. This is one reason flood plains have rich soil.
Time	Soil formation is a continuous process, occurring over thousands of years.

What is the most common type of soil parent material in your area?

Table 3. Physical processes that influence soil formation

Physical Processes	Description
Additions	Anything that is added to the soil, such as organic matter or salts, is an addition. Additions can occur naturally or when amendments are added, such as fertilizer, construction material, and mulches.
Losses	Minerals can be washed out or leached from the soil, and both inorganic and organic matter can be lost through erosion.
Translocations	Soil materials may be transported from one site to another but not lost from the system. For example, soil eroded on a hill is deposited in a low-lying area below. As water moves through the soil and evaporates, it can leave salt accumulations behind.
Transformation	The chemical and physical properties of the soil can be changed over time. Microorganisms, for example, that feed on dead plant and animal matter transform it into humus.

Soil Horizons

Over time, soil is formed into different layers called "horizons." The arrangement and make-up of these horizons influence root growth and development. The thickness of each layer will vary, depending on site conditions. There are many types of horizons, but all are not found at every site. Below these horizons or layers of soil is the bedrock that forms the parent material of the soil. It may be close to the surface or hundreds of feet below it. Table 4 describes the four general horizons in a soil profile.

Table 4. Soil horizons

Horizon	Description
O horizon	This top layer or organic horizon consists of decaying plant material, called "humus." This horizon is usually darker than the other layers because of its organic content.
A horizon	The A horizon, below the O horizon, is the most productive layer of soil and is commonly referred to as "topsoil." Most of a tree's absorbing roots are found in this horizon. The A horizon is composed primarily of mineral material and is generally darker than the lower horizons because of the humus material that has been incorporated into it.
B horizon	This subsoil layer is formed by materials leached and otherwise moved from the A horizon, including clay, iron, aluminum, and organic material. It also contains soil particles from the lower parent material. The B horizon is generally lighter in color, denser, and lower in organic material than the A horizon
C horizon	This lowest layer of soil is composed of disintegrated parent material and other minerals.

Soil Profile

A soil profile is a vertical cross-section of a soil, showing the soil horizons. The soil profile may be altered by construction and other land disturbing activities, such as grading, cutting and filling, and cultivation. These activities can disrupt the soil horizons, for example the O horizon may be very thin or nonexistent. These changes or disruptions to the natural soil profile directly influence drainage, aeration and root penetration of the soil.

Knowing the soil profile and how it has changed is helpful in predicting potential drainage problems at a site.

Depth

Soil depth is generally defined as the distance from the surface of the soil to an impenetrable layer, such as bedrock, or to a water table. Buried construction materials, such as concrete and pavement, will also limit soil depth. Trees need soils that are deep enough to drain adequately and also to provide sufficient moisture, space for root development, and physical support. Naturally, deep soils usually hold more moisture than shallow soils.

Soil Series

Soils with similar profiles and properties are grouped into "series" to help classify and describe them. The names of series usually come from the geographical areas where they were first found and described and are modified by the texture of the surface soil (Harris 1992). Being familiar with the soil series can help in selecting a tree species and predicting its growth or in gauging the soil erosion potential in a specific area. Here are some examples of soil series that have different characteristics (U. S. Department of Agriculture Natural Resource Conservation Service):

Wilkes sandy loam

This shallow, well-drained soil occurs on narrow ridges and hillsides of uplands. The subsoil is brown, loamy, and less than 20 inches thick over bedrock. Permeability is moderately slow and available water capacity is low.

Chastain loam

This deep, poorly drained soil occurs on flood plains. The subsoil is gray and clayey, extending to a depth greater than 40 inches. The seasonal high water table is 0 to 1 foot. Flooding is common. Slopes are less than 2 percent. Permeability is slow and available water capacity is moderate.

What are the common soil series in your area?

Soil Surveys

Soil surveys are maps detailing information on soil type, texture, bulk density, water-table height, rock layers, hardpan, drainage patterns, percolation rate, slope, and vegetation. They can be useful in urban areas because of the information they provide about the parent material or bedrock that is the original source of the soil, if the soil has not been moved or disturbed. By identifying the parent material, it is usually possible to determine many properties or characteristics of the soil..

Contact the Natural Resource Conservation Service office for more information on soil series and surveys.

Checking Your Understanding of Soil

1.What are the four basic substances that make up soil?

2.What two layers or horizons of soil chiefly influence a tree's root growth? Where are they found?

3.How can a soil survey be helpful in an urban area?

Answers are at the end of the unit.

Soil Characteristics Important for Tree Growth

Understanding the basic physical, chemical, and biological properties of soil and their interaction helps to identify and correct problems that affect tree growth. Good soil conditions provide the water, oxygen, and nutrients necessary for a tree's growth and development. A number of soil characteristics are discussed in this section:

- Pore space
- Texture
- Structure
- Bulk density
- Aeration
- Soil moisture
- Nutrients and soil fertility
- pH
- Biological components
- Color
- Temperature

While each of these characteristics is important, it is the combination of them at a particular site that influences a tree's growth and vigor.

Soil conditions are often more important to a tree's health than above-ground conditions.

Pore Space

The space between soil particles is called pore space (figure 1). The size, number, and distribution of these pores influence how air, water, and dissolved nutrients move through the soil. There is no ideal percentage of pore space in soil because each tree species requires different amounts of air and water.

Pore space is easily diminished when soil is moved, disturbed, or compacted. This reduction in pore space also reduces the movement of air and water in the soil, which impacts root growth. There are two types of pores, macropores and micropores.

Macropores

These are large pore spaces between soil particles that are typically filled with air. They also allow water and dissolved nutrients to freely move through the soil.

Micropores

These are the small pore spaces that hold water and dissolved nutrients after excess water has moved through or drained from the macropores.

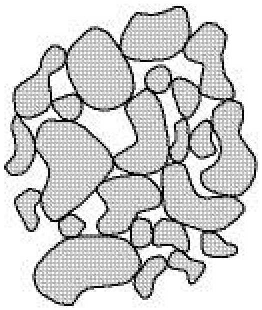


Figure 1. Pore space (white areas) is the area between the soil particles (dark areas). (Illustration adopted from International Society of Arboriculture Arborists' Certification Study Guide; Illustration drawn by Gene Wright)

Texture

Soil texture refers to the relative size (fineness or coarseness) and the proportion of the sand, silt, and clay particles in the soil. Sand particles are the largest and clay the smallest, with silt between the two in size (Harris 1992) (table 5). Soil texture influences soil fertility and the way air and water move through the soil. Knowing the soil texture at the site will help with evaluating drainage, aeration, and nutrient content..

Table 5. Characteristics of different soil textures

Soil Texture	Characteristics
Sand	Sandy soils typically have coarse texture, large pores, good permeability, good drainage, good aeration, and poor fertility. Soil is considered sandy if it is more than 45% sand.
Clay	Clayey soils have fine texture, small pores, poor permeability, poor aeration, poor drainage, higher fertility than sandy soils, and are easily compacted. If the soil averages 35% or more clay, the soil is considered clayey.
Silt	Silt is intermediate in texture between sand and clay. The soil is considered silty if more than 40% is silt.
Loam	Soils that have characteristics of all three textures – sand, clay, and silt – are called "loams." For example, a soil with 35% sand, 35% clay, and 30% silt is called a clay loam. Loamy soil usually has a good texture for growing a wide variety of trees.

Textural name

Soils are named by the dominant particle size – sand, clay, or silt. Soils that have the characteristics of all three types of soil particles are called loams. Because it takes less clay to dominate the characteristics of a soil, it takes only 20% clay to include clay in its name, such as sandy clay loam. Clay soil, however, needs to be at least 35% clay. The textural name of a soil can be found by using the soil textural triangle shown in figure 2.

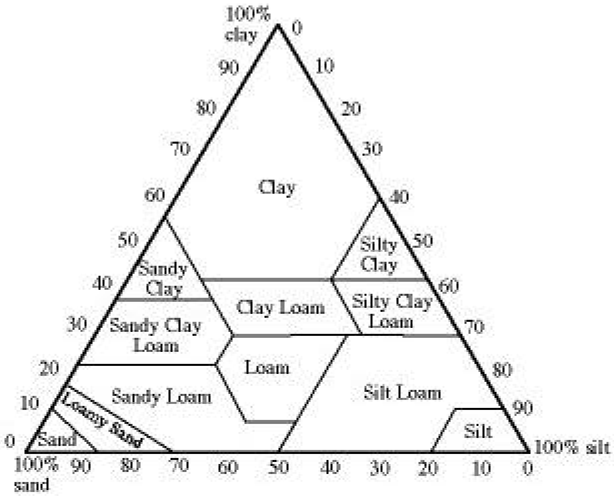


Figure 2: Soil texture triangle

Soil interfaces

Soil interfaces are abrupt changes in the texture of soil that can occur naturally such as through erosion or mudslides. They can also be caused by adding anything to the soil that is different in texture than the native soil. This can include bricks, other building materials, and fill soil that is a different texture. These interfaces interrupt the normal movement of water in the soil.

Construction debris is sometimes buried in the soil which can cause soil interface problems.

Evaluating soil texture in the field

Kneading the soil between the thumb and forefinger is a simple test to determine soil texture:

- Sand has gritty particles
- Clay feels sticky or slick
- Silt has flour-like or talc powder feeling

A more accurate analysis can be obtained by sending a sample to a soil laboratory.

Structure

Structure is the way soil particles – sand, silt and clay – are grouped or bound together. These clumps of soil are called aggregates, and between these clumps are pore spaces. A well-structured soil for healthy root growth has adequate pore space for water movement and gas exchange. There are different types of soil structure, such as crumb or columnar, based on the shape of the aggregate.

Soil aggregates are fragile and easily damaged. If soil is disturbed by such site activities as clearing or compaction, the aggregates can be crushed, which decreases pore space and increases such problems as drainage, moisture and nutrient flow, and resistance to root penetration. Calculating a soil's bulk density is a way to test for soil structure that is disturbed or compacted.

Bulk Density

Bulk density, the measure of the soil's weight per volume, describes a soil's mass, density, compactness, or how closely the soil particles are packed together. If a soil has a high bulk density then it is most likely compacted. Compacted soil has little pore space and poor soil structure, which limits air and water flow and root growth. Table 6 lists some common bulk densities that may be helpful for understanding the bulk- density measurement at a particular site (Harris 1992).

Table 6. Comparison of common bulk densities.

Type of Material	Bulk Density Measurement
Normal soils	1.0 to 1.6 grams/cm3
Soils with restricted root growth	1.4 to 1.6 grams/cm3
Bricks	1.4 to 2.3 grams/cm3
Soil commonly found at construction sites	1.7 to 2.2 grams/cm3

Check local soil survey for information about bulk densities in your area.

Testing for bulk density

The bulk density of the soil is tested by measuring a soil sample from the site. This can be done by using the core sampler test or by sending the soil sample to a laboratory.

- Core sampler test
  Insert a core cylinder of known volume into the ground to collect a soil sample. Oven dry the soil sample for 24 hours and then weigh. Calculate the bulk density by dividing the weight of the oven-dried soil sample by the volume of the sample.
- Laboratory test
  Contact the local Cooperative Extension Service or USDA Natural Resource Conservation Services for information about laboratory testing.

Bulk density tends to increase with the depth of the soil.

Root penetration

A root's ability to penetrate a given sample of soil can be tested by using a penetrometer. Resistance to penetration is measured as the probe is pushed into the ground. A penetrometer can be purchased through a forest products supplier.

Aeration

Soil aeration is both the movement of air within the soil and the exchange of air with the atmosphere. Aeration is important because root and shoot development depends on this normal exchange of gases, including oxygen, in the soil. During respiration, roots absorb oxygen from in the macropores and release carbon dioxide. Water moving through the soil macropores forces carbon dioxide out and atmospheric oxygen is pulled in. Aeration can be a problem in heavy clay, compacted, or water logged soil because pore space has been reduced or pores are filled with water. When there is poor soil aeration, anaerobic (no oxygen) soil conditions develop, the soil turns gray or blue and plant growth is limited.

Testing soil aeration

Testing the bulk density of the soil can also help determine if there is an aeration problem.

Most roots grow in the top 18 inches of soil where soil oxygen is most readily available.

Soil Moisture

Moisture in the soil is essential for healthy tree growth and development. It contributes to tree health in three different ways:

- Water from the soil replaces the water in the tree that is lost through transpiration.
- Essential nutrients for tree growth and development, such as nitrogen, phosphorous, and potassium, are dissolved in soil water and absorbed by the roots.
- Water is held by the soil and supplied over time to meet the needs of the tree. The water-holding capability depends on the soil type.

The symptoms for too much and too little water are the same, browning leaf edges.

How water moves through soil

Water can move in all directions in the soil: upward to evaporate from the soil surface, downward after rain or irrigation, and side-to-side when it cannot move downward because of bedrock, compacted soil, or saturated soil. Gravity and capillary action control how water moves in soil.

- Gravity
  Gravity pulls water downward through the macropores in the soil. This water is called gravitational water.
- Capillary action
  Capillary action is the force that pulls water in any direction. Pore size and the soil's ability to attract and hold water determine how much water is moved by capillary action.

How water moves through the soil is also influenced by the permeability, infiltration rate, and retention rate.

- Permeability
  Permeability is how easily water moves through the soil. In sandy soils, permeability is usually high because of the coarse texture and large pores. In clay soils it is low because the small pores reduce water's ability to move.
- Infiltration rate
  The infiltration rate is how fast water moves through the soil. Typically, the larger the pore size the faster the movement of water. Sandy soils have a high infiltration rate; clay soils have a low infiltration rate.
- Retention rate or water-holding capacity
  Retention is how well a soil holds water. The small pores of fine-textured soils (clays) tend to hold more water than coarse-textured soils (sandy).

Soil moisture

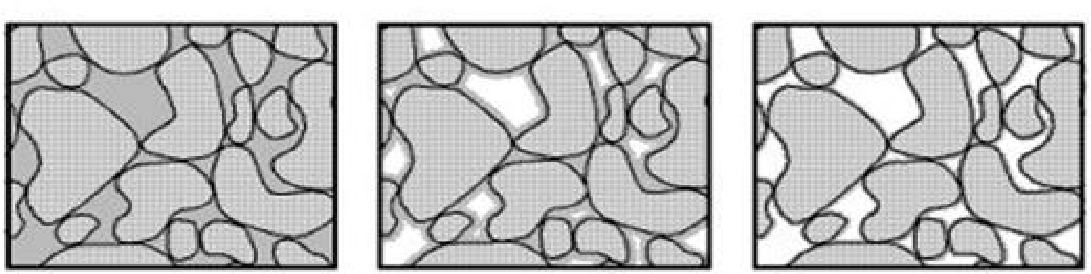
Typically, when water enters the soil, it fills up the pore spaces between the soil particles and forces air out of the soil. When the water flows out of the soil, it pulls air back into the macropores. The water that remains in the soil is in the micropores, and this is the water that is available to the roots. There are three different moisture levels in the soil, depending upon site conditions (figure 3):

- Saturation point
  When the soil pores are filled with water and the water is not draining away, the soil has reached the saturation point. The water forces all the oxygen out of the macropores. Without the soil oxygen, the roots will start to die. Flooding and over irrigation can cause soil to reach the saturation point.

- Field capacity
  Field capacity is reached when the water contained in macropores has drained away leaving water in the micropores available for aborption by the roots or for evaporation. For most trees, roots grow best when the soil moisture condition is at field capacity.

The difference between field capacity and permanent wilting point represents the water that is available for plant growth.

- Permanent wilting point
  Permanent wilting point or drought condition is when there is no usable water in the soil for a tree. This is the point where the tree cannot pull water from the micropores in the soil. When the tree reaches permanent wilting point, it usually starts to decline and die.



a) saturation point *b) field capacity* *c) permanent wilting point*

Figure 3. Soil moisture conditions (pattern areas are soil particles, dark areas are water and white areas are air). (Illustration adopted from International Society of Arboriculture Arborists' Certification Study Guide; Illustration drawn by Gene Wright)

Testing for soil moisture

Soil moisture conditions can be tested in at least two ways:

- By feel or appearance (table 7)
- By using a tensiometer or soil moisture meter - a probe that measures soil moisture. A tensiometer can be purchased from a forest products supplier.

Table 7. Testing for soil moisture by feel or appearance in sandy loam and clay loam soils (Harris 1983)

Soil Moisture Available for Trees	Sandy Loam	Clay Loam
Close to 0% (Little or no moisture available.)	Dry, loose; flows through fingers	Dry clods that break down into powdery substances
50% or less (Approaching time to irrigate)	Still appears to be dry; will not form a ball	Somewhat crumbly; will hold together with pressure
50% to 75% (Enough available moisture)	Tends to ball under pressure but will seldom hold together	Forms a ball; somewhat plastic; will sometimes stick slightly with pressure
75% field capacity (Plenty of available moisture)	Forms weak ball; breaks easily; will not become slick	Forms a ball and is very pliable; becomes slick readily if high in clay
At field capacity (Soil will not hold any more water (after draining)	Upon squeezing, no free water appears, but moisture is left on hand	Same as sandy loam
Above field capacity (Unless water drains out, soil will be water logged)	Free water is released after kneading	Can squeeze out free water

Nutrients and Soil Fertility

Trees require nutrients to survive and grow. Most nutrients occur in the soil as the result of the weathering of the parent material or the decomposition of organic matter. Nutrients also come from fertilizer, water, and air. These nutrients are either absorbed by roots, held by the soil in the pore spaces, or leached deeper into the soil. Thirteen of the 16 nutrients essential for tree growth are usually derived from the soil and three (oxygen, carbon, and hydrogen) are taken from air and water (table 8). Nitrogen is the nutrient most likely to be deficient in the soil. A lack of nitrogen often results in yellowing leaves. Additional information about nutrients appear in the *Tree Maintenance* unit.

Table 8: Nutrients found in the soil

Macronutrients	Micronutrients
Nitrogen Phosphorous Potassium Calcium Magnesium Sulfur	Boron Chlorine Copper Iron Manganese Molybdenum Zinc

Absorption is the process of taking elements inside, while adsorption indicates that the elements are incorporated on the surface.

Factors that influence nutrient availability and soil fertility

- Nutrients soluble in water
  The nutrients most available to the roots are those dissolved in soil water. However, in this soluble form the nutrients are more readily leached or washed down through the soil. At some soil pH levels nutrients become insoluble in water and therefore are not available to the roots.
- Leaching
  Leaching occurs when water washes nutrients down through the soil. Nitrogen and other elements tend to leach down from the root zone, making them unavailable for plant growth. Sandy soils tend to have a greater nutrient loss from leaching than clay soils.

Nutrients that can be adsorbed onto soil particle surfaces are less susceptible to leaching.

- Cation exchange capacity
  Soil fertility depends on the ability of the soil particles to adsorb nutrients on their surfaces. Soil particles are negatively charged and attract positively charged nutrients called cations, which include calcium, magnesium, sodium, potassium, hydrogen, and aluminum (figure 4). The soil's ability to attract and adsorb positively charged nutrients is called the cation exchange capacity. Soil particles that attract the most charged nutrients or cations will be the most fertile. Highly fertile soils have large quantities of the nutrients trees need for growth readily available. The fine-textured particles of clay soil are negatively charged and have

a greater cation exchange capacity than the particles in sandy soil. Thus, fine-textured soils are usually more fertile than coarse-textured ones. Nitrogen is negatively charged and so is not as easily attracted to soil particles, which explains why it is likely to be deficient in the soil. A laboratory soil analysis can reveal the cation exchange capacity of a soil.

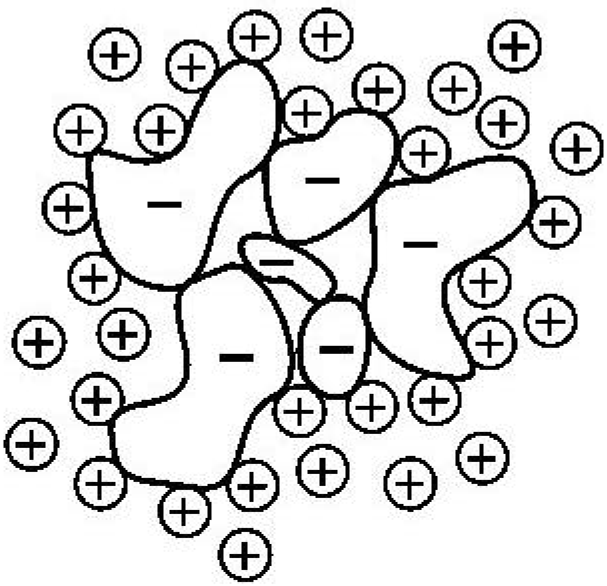


Figure 4. Cations are attracted to and held by negatively charged soil particles. (Illustration adopted from International Society of Arboriculture Arborists' Certification Study Guide; Illustration drawn by Gene Wright.)

- Nutrient cycling
  Nutrient cycling is the process of a plant absorbing nutrients from the soil to grow and then releasing them back to the soil when it dies and decomposes. In urban environments, nutrient cycling is often disrupted because plant debris is not left on the ground to decompose.

Testing for a nutrient imbalance
These are three ways to determine if there is a nutrient imbalance in the soil:

- Symptoms
  Some typical symptoms characteristic of a nutrient imbalance include yellow leaves, brown leaf margin, early or late leaf drop and irregular branching pattern.
- Soil analysis
  Soils are tested for pH and the amount of phosphorous, potassium, calcium, zinc, manganese, organic matter, and other nutrients. Soil test kits can be purchased from garden centers or forest products suppliers. A soil sample may also be sent to a laboratory for testing.
- Plant tissue analysis
  A plant tissue analysis can be conducted by a laboratory to test for minerals, nitrogen, sulfur, and carbon in tree leaves.

The results of an analysis will include information about fertilizer requirements or pH adjustments needed to increase the availability of nutrients.

Contact the local Cooperative Extension Service or Natural Resource Conservation Service for information on soil and plant tissue analysis.

pH

Soil pH is the measure of the acidity of a soil. This affects the availability of some nutrients in the soil and the activity of microorganisms. The pH scale ranges from 1 to 14. A pH of 7 is neutral, a pH above 7 is alkaline or basic, and a pH below 7 is acidic (figure 5). A pH range of 5.5 to 6.5 is often given as the most favorable for tree growth. However, some tree species grow better in acidic soils and some better in alkaline soils. At certain pH levels some nutrients become insoluble in water and are not available to roots. For example, in acid soils, calcium and magnesium are less available and in alkaline soils, iron, manganese, zinc, and copper are less available. It can be difficult to change the pH if there is a large volume of soil involved, but adding lime may raise the pH and adding sulfur may lower the pH.

Soil pH is an important consideration when selecting a species. Native species generally grow well in local soil, unless the soil has been disturbed.

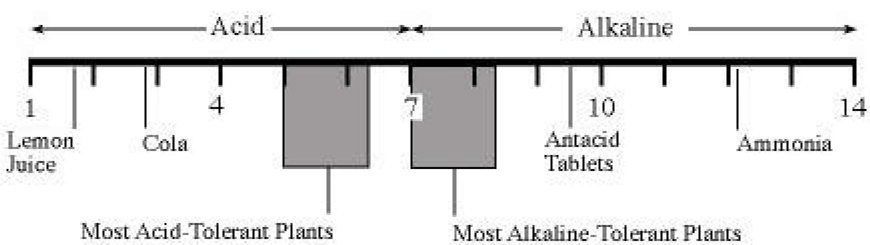


Figure 5. pH scale (Illustration courtesy of the Morton Arboretum, Tree Care Handbook; Illustration drawn by Gene Wright)

Testing soil pH

- Field test kit
  Soil pH can be tested with a field test kit that can be purchased at most garden centers or from a forest products supplier.
- Laboratory test
  Contact the local Cooperative Extension Service or Natural Resource Conservation Service for information on testing soil pH. The laboratory test report will usually include recommendations for type and amount of amendments needed.

Being familiar with soil pH can help in diagnosing tree health problems because pH levels influence nutrient availability.

Biological Components

There is a multitude of living organisms in the soil that affect its physical and chemical properties. These can both positively and negatively affect tree growth. Soil organisms are essential in improving soil properties because they provide organic matter, soil aeration, and expanded root surface area. However, some are hazardous to trees.

Plants

Types of small plants or microflora in soil include algae, bacteria, and fungi. Many of these help decompose organic matter, but some do cause plant diseases.

Mycorrhizae

Mycorrhizae are beneficial fungi that invade young lateral roots on most trees. Research indicates that the mycorrhizae increase the surface area of roots, increasing the potential for nutrient and water uptake. Trees with established mycorrhizal roots tend to be more vigorous than those without.

Animals

Many small organisms, such as earthworms and insects, decompose organic matter and increase soil aeration, which greatly benefits root development. Some soil organisms, such as some nematodes, parasitize and harm tree roots.

Color

Soil color often reflects the condition of the soil and its ability to sustain a healthy environment for plant growth. Changes in normal soil color may result from changes in the chemical and physical properties of the soil. This may occur with the addition of fill dirt or the dumping of waste.

- Dark soil near the surface is a common indicator of high organic content.
- Gray color usually indicates wet soil with high iron content.
- Gray or blue soil suggests there is an aeration problem due to wet soil conditions.

Soil color evaluation

One of the most widely used guides for soil color evaluation is the Munsell System. In a process similar to the one used to match paint samples, soils are assessed by comparing them with the color sample in the guide. The Munsell System or other color reference guides can be purchased from forest products suppliers.

Change in soil color may indicate potential site problems for trees.

Temperature

The temperature of the soil influences root growth by controlling the rate of the chemical and biological processes. The most favorable temperature for root growth depends on the species, but it is generally 70-83 degrees Fahrenheit. Roots are sensitive to extremes in soil temperature which can reduce root growth or damage roots.

Low soil temperature

- Slows the biological and chemical activities.
- Freezes the roots.
- Increases the weathering of soil through freezing and thawing.

High soil temperature

- Increases activity of disease-causing microorganisms.
- Dries out or desiccates the roots, causing them to become thin and light brown.

What locations in your community would you expect to have higher soil temperatures?

Checking Your Understanding of Soil Characteristics Important for Tree Growth

On a separate sheet of paper, briefly answer the following questions:

1.What three things can you predict by knowing the texture of the soil? Define each of the terms you listed.

2.What makes soils fertile? What type of soil is usually the most fertile?

3.What are three reasons soil water is important for tree growth?

4.Why is it important to know soil pH?

Answers are at the end of the unit.

Common Soil Problems in Urban Areas

Many activities in urban areas change the soil's physical, chemical, or biological characteristics. Some of the most common activities including construction, maintenance activities are discussed in this section, and possible solutions are suggested.

Construction can cause soil problems in urban areas because these activities often alter the soil profile and change soil characteristics.

- Impervious surfaces, such as buildings and roads, interrupt the natural exchange of gases, increase soil temperature, and alter drainage patterns. The heat-holding capacity of these hard surfaces increases the soil temperature.
- Heavy construction equipment and material storage areas compact the soil.
- Moving soil, such as grading, clearing, and excavating, influences drainage and aeration and causes erosion.
- Chemical spills, such as cement washout areas or painting sites, contaminate the soil.
- Removal of topsoil diminishes soil fertility.
- Use of fill dirt influences soil drainage, aeration, and fertility.
- Dumping or burying waste materials, such as dry wall and garbage, may change drainage patterns and contaminate the soil.

Other practices impact the soil conditions at a site.

- Poorly timed irrigation systems can cause soil moisture problems.
- Removal of organic matter influences soil fertility and moisture.
- Excessive herbicide or fertilizers contaminate the soil.
- Foot traffic from pedestrians and road vibrations compact the soil.
- Backyard chemical spills, such as gasoline and oil, contaminate the soil.

In urban areas these construction and other activities can disturb the original soil profile. Consequently, there are typically a wide variety of profiles. The O horizon may be 6 inches deep or it may be absent because leaves and other organic materials have not been left to accumulate on the ground. In construction areas the O, A and B horizons may have been removed or the B horizon might be on top of the A horizon. Debris in the soil or abrupt changes in soil texture can also change the soil profile.

Soil Compaction

Soil compaction is a major cause of tree decline in urban areas. Compaction occurs when a force, such as feet, vehicles, and even water from some sprinkler systems, creates pressure on the soil surface and compresses the soil particles. This force causes the soil aggregates to break into smaller particles, reducing the amount of pore space in the soil. The reduced pore space hinders aeration, water infiltration, and root penetration. A lack of soil oxygen and poor water drainage retard root growth, jeopardizing the health of the tree. Table 9 lists some common signs of compaction. Techniques to prevent compaction are listed in Table 10.

Construction activities often compact the soil.

Table 9. Signs of compaction

Sign	Description
Hard soil	If it is hard to penetrate with a shovel, the soil is probably compacted. Earlier cultivation may have produced a layer of hard soil 10-12 inches below the surface.
Standing water	Water standing on top of soil for long time may indicate compaction.
Excessive water runoff	This is a sign that there is low permeability or little movement of water through the soil.
Loss of vegetation or poor plant growth	Compacted soil does not allow the necessary air circulation and water infiltration into the root zone. A lack of sufficient water, nutrients, and oxygen to the roots causes declining tree health or death.
Bulk density	A high soil bulk density usually indicates compaction. The reduced pore space limits water infiltration, aeration, and root growth.
Surface crust	Development of a surface crust sometimes occurs with the compaction of fine-textured soils. This crust limits the infiltration of air and water to the soil and increases runoff and erosion. Surface crusts are usually found on soils subject to heavy foot traffic, such as playgrounds and footpaths.

Table 10. Techniques to prevent compaction

Technique	Description
Avoid wet soils	Always work with dry or moist soils, never with wet soils.
Limit travel routes and parking areas	Limit travel by both people and vehicles to a few paths, and do not park vehicles under trees. For pedestrian traffic, a raised wooden path can prevent compaction. Vibrations from construction equipment can compact the soil.
Apply mulch	Spread a layer, no more than 6 inches thick, of coarse mulch, such as wood chips or bark, on soil surface in the area likely to be compacted. The mulch should not touch the tree trunk. A thicker layer of mulch can be used temporarily during construction.
Use light weight vehicles	Try to use only lightweight vehicles with large, smooth, low-pressure tires.
Apply surface grating	Place metal grates over the planting site to prevent people from walking on it.
Know soil type	Find out the type of soil at the site. Fine-textured, clayey soils are more easily compacted than coarser, sandy soils.

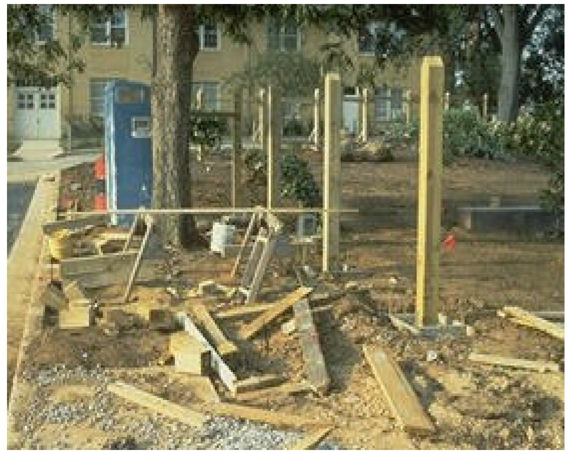
Solving compaction problems
Compaction is difficult to correct; however, Table 11 lists several techniques that may help solve compaction problems. The best option depends upon the conditions at the site, whether this is a new planting or an existing tree, and the available resources.

Table 11. Techniques for solving soil compaction problems for new and existing planting sites.

Techniques For New Planting Sites	**Description**
Soil mixing	Compacted soil can be mixed with a fully composted organic mulch to improve the soil quality, but up to 50% volume of soil is needed to make this technique useful.
Rototilling or grading	For a new planting site, the compacted layer of soil may be rototilled, disked, or graded to promote water infiltration.
Subsoiling or drilling hardpan	If there is a compacted layer of soil 1 or 2 feet below the surface, subsoiling or deep plowing with a plow or backhoe when the soil is dry may break up this impermeable layer. If subsoiling is impractical, holes can be drilled through the hardpan to provide drainage and better root penetration (Harris 1992). If there are existing trees near the site, care must be taken not to damage the roots.
Top Mulching	In both new and existing plantings, the organic content of soils can be increased by adding mulch on top of the soil. However, organic material takes many years to breakdown and combine effectively with the soil.
Techniques For Existing Planting Sites	**Description**
Core aeration	Pore space in compacted soil may be increased by removing small soil cores to a depth of about 3 inches.
Vertical mulching	Holes 1 - 2 inches in diameter may be drilled in the compacted soil and filled with perilite, vermiculite, or other amendment material.
Radial trenching	Trenches 6 - 8 inches wide and no deeper than the root system or depth of compaction can be dug with trenching equipment. The trenches are dug around the trunk of an existing tree in a bicycle-spoke pattern, extending from the trunk and backfilled with a mixture of soil and amendments.

Reduced Soil Aeration

Many soils in urban areas have poor aeration because of soil compaction and poor drainage. Aeration problems also occur when the soil is contaminated by salts and excessive fertilizer.

Storage of fill soil and construction material can reduce soil aeration.

Signs of poor aeration

- High soil bulk density
- Water-logged soil
- Standing water
- Gray or blue soil
- Foul smelling soil
- Poor plant growth
- Grade changes

Solving reduced soil aeration

Aeration problems can be prevented or corrected by many of the same methods described for reducing soil compaction. If poor drainage is reducing aeration, a drainage system may need to be installed.

Excessive Soil Moisture and Drainage Problems

Soils with excessive moisture have poor aeration because pore spaces are filled with water. Roots tend to grow near the surface in such soils. With poorly anchored roots, a tree is susceptible to wind throw. A tree may survive for a time, but the roots will eventually die and decay from lack of oxygen in the soil, leaving the tree without a way to absorb necessary water and nutrients. Too much water in the soil is often caused by construction and planting practices, such as the improper use of irrigation systems. However, some locations are naturally susceptible to saturated soil because of soil type, terrain, heavy rains, flooding, or a high water table. For example, soils with high clay content tend to have more drainage problems then sandy soils because they are more easily compacted. Table 12 describes some typical signs that drainage may be a problem at the site. Techniques to prevent compaction are listed in table 13.

Construction activities can alter drainage patterns at a site.

Table 12. Signs of drainage problems

Sign	Description
Water movement	A large amount of water flowing quickly over soil may indicate saturated soil conditions. This can also cause erosion.
Standing water	Water left standing after a rain may also indicate excessive moisture in the soil.
Soil type	The type of soil at a site influences moisture conditions. Sandy soils usually have a high infiltration rate with water moving quickly through, while clay soils tend to retain water.
Browning leaf edges	Edges of leaves turning brown may indicate too much soil moisture.
Root decay	Waterlogged soils can cause root decay.

Table 13. Preventing drainage problems

Technique	Description
Modify construction practices	When soil is moved or disturbed by activities such as grading, drainage patterns may be changed, affecting soil moisture conditions. Grade the soil during construction and landscaping so that no low spots are created at the planting site. Maintain the natural horizons during grading or filling so that infertile subsoil does not become the top layer of soil. Drainage problems can be avoided by minimizing the amount of soil compaction that occurs at a site. Keep debris, such as rocks and bricks, out of the topsoil to prevent interfaces or changes in soil texture. Impervious surfaces, such as concrete and asphalt, can inhibit water evaporation from a site. This can cause poor drainage and excessive moisture conditions.
Break up hard pan	Below ground soil layers that are impervious to or restrict water infiltration can cause problems. Hardpan that occurs within 30 inches of the surface should be penetrated. Tractor-drawn subsoilers can be used for large sites, while digging and drilling holes often work in smaller areas.
Use care in site and tree selection	For a location that is continually subject to excessive soil moisture, select a species that is tolerant of wet conditions. A site should have adequate soil volume to support the growth and development of the species selected. Avoid selecting a site where layers of rocks are near the soil surface, because there is little soil to absorb the water. Raised-bed planters are an option that elevates the tree’s roots out of the saturated soil. At sites with poor drainage, select a species that is tolerant of wet conditions.
Adapt planting methods to site conditions	Plant the root ball so the crown is slightly above the soil level. Use coarse-textured fill material, such as sandy loam or loamy sand, to improve aeration and drainage. Do not use soil with a high clay content as fill material. Soil conditions that should be avoided include gravel under loam and sand on top of clay.
Regulate irrigation systems	Setting irrigation systems to deliver water based on need, instead of time, will help prevent excessive soil moisture.

Testing for drainage problems
Follow these steps to determine if there is a drainage problem (Gilman 1997):

- Dig a 12-by-12-inch wide hole and fill with water
- Drainage is good if the water drains from the hole in an hour.
- If the water takes from several hours to a day to drain from the hole, drainage is fair.
- If water stands in the hole for more than a day, there is either a high water table or poor drainage.

Solving drainage problems
Excessive soil moisture can sometimes be solved by providing proper drainage for the tree, but this can be difficult and often expensive to correct. Proper planting procedures and selecting a species adaptable to the site are the best means for dealing with excessive moisture that cannot be corrected without drainage techniques. As a last resort, a drainage system can also be installed, depending upon the site conditions and available resources. Table 14 describes three common techniques.

Table 14. Drainage systems

Technique	Description
Install drain pipe or tile	To eliminate minimal drainage problems, drain pipes or tiles can be installed to move the water away from the tree. Although tile is the traditional pipe for below-ground drainage in large agricultural settings, the cheapest and easiest material to use for small sites is plastic pipe.
Install perforated pipe	A perforated pipe wrapped with screening material may be installed if planting in extremely heavy clay or waterlogged soil. The size of the pipe depends on the amount of water that needs to be drained.
Dig a french drain	The French drain is a trench 2-4 inches wide cut from the wet area to a lower-lying dry area. It is filled with small gravel or large sand particles to a point slightly above the level of the surrounding soil. A pipe may need to be put at the end to carry water away from the tree.

Contact the USDA Natural Resource Conservation Service, engineer or landscape architect for additional information on installing a drainage system.

Low Soil Moisture

Lack of moisture in the soil is as harmful as too much water. Low soil moisture can be caused by high temperature, drought, high salt content, sandy soils, and improperly timed irrigation systems. Impervious surfaces can also prevent water from entering the soil. Signs that low soil moisture may be a problem include browning leaf edges and dry soil. Properly timed irrigation systems, watering during drought periods, and mulching can help prevent tree health problems caused by low soil moisture. Once the tree has reached the permanent wilting point from lack of water, it will be in a state of decline.

Nutrient Imbalance

Soils in urban areas may have a nutrient imbalance. If there are inadequate nutrients, tree growth and development will be affected. Often nutrient imbalances are caused by high pH levels, low soil fertility, or high salt content.

High soil pH

Urban soils may have a high or alkaline pH because construction materials, such as mortar and concrete, are often spilled or left on the soil. The addition of this calcium-based material, which is alkaline, raises the soil pH. Some species of trees need an alkaline soil, but other species can not tolerate a high pH level. A high pH may also cause chemical reactions with nutrients in the soil that render the nutrients unavailable to the tree. Iron, for example, becomes unavailable for a tree's growth processes when soil pH is alkaline. Sulfur may be added to soil to lower the pH. Tolerance to the local soil conditions needs to be considered when selecting a tree to plant in an urban area.

Low soil fertility

There are several common reasons for low soil fertility in urban environments.

- Topsoil and organic matter are often removed from a site during construction.
- Leaves are removed from the soil surface and not allowed to decompose. This reduces the amount of nitrogen, phosphorus, and other nutrients in the soil.
- Biological components and organisms are not as common in urban soils. This limits soil aeration and the addition of organic matter to the soil.
- Changes in soil chemistry may influence the availability of soil nutrients, interrupting the nutrient cycling process.

Top soil is often removed during land development.

High salt content
The salt level in soils may be elevated because of de-icing salts, excess fertilizer, or irrigation water high in soluble salts. This can be a problem, particularly in areas with low rainfall and extensive use of irrigation and fertilizer (Harris 1992). A soil that is high in salts has less water available to the roots. Sometimes salts can even draw moisture out of the roots. High salt levels can sometimes be reduced by leaching the salts with proper watering techniques.A symptom of high salt content in the soil is browning of leaf edges. If the soil does have a high salt content, select a species that is tolerant to high salts.

Soil Contamination

Soil can be contaminated by masonry, wood, paper, asphalt, paint, fuel, cement, oil, salt, or other materials. Contamination may occur across an entire site, such as an industrial property, or in spots, such as concrete washouts and refueling areas. This damage can also occur in the backyards of homes when cat litter or engine oil is dumped, or where there has been excessive use of pesticides and herbicides. Soil contamination often reduces aeration and water infiltration and sometimes may kill tree roots.

A change in soil color may indicate chemical contamination at the site.

Temperature Extremes

Temperature extremes can alter the chemical and biological characteristics of soils. Urban locations often have higher soil temperatures than rural areas because of the heat that is absorbed by and reflected from buildings, sidewalks, streets, and vehicles. This is the "heat-island" effect. Temperature differences also occur in a city because of the height of the buildings or directions of the streets (north/south or east/west). High air temperature raises the temperature of the soil. A lack of mulch and other debris on top of the soil also influences the soil temperature. Mulching is one of the easiest ways to reduce extreme soil temperature.

Erosion and Siltation

Site clearing and land grading are two construction activities that typically increase soil erosion. These actions change the soil profile and structure, affecting the stability of the soil aggregates and the water infiltration rate. Not only does the site lose soil, but the resulting sediment can interrupt the normal exchange of soil gases. The effects of erosion may be reduced by redirecting or reducing the flow of water.

Construction activities can cause soil erosion.

Signs of erosion

- Loss of soil at the site
- Visible roots
- Poor growth
- No basal flair of the trunk

Preventing erosion

- Establish vegetative buffers
- Install erosion fencing and geotextiles
- Minimize the area of disturbance
- Plant temporary vegetative cover
- Mulch

Checking Your Understanding of Characteristics of Urban Soil

On a separate sheet of paper, briefly answer the following questions:

1. What are three major problems caused by soil compaction? List two ways that compaction can be prevented and two ways to improve soil that is already compacted.

2. Selecting a tree species that tolerates excessive moisture is the best method for preventing problems in an area that consistently has wet soil. When excessive moisture is caused by other problems, what are three ways that it can be prevented?

3. When consulting with a property owner about an unhealthy tree, what are some soil conditions that you might look for or ask about?

Answers are at the end of the unit.

Case Study

Unearthing the Past

The local community center had finally received permission from the city to create a small park on a vacant piece of property. The plan was to plant a few trees, put in some park benches, and establish a neighborhood vegetable garden. The people living nearby had all agreed to pitch in to do the work and to share the vegetables they would raise. They thought it would be a simple project – just haul away the trash, pull up the weeds, rototill the soil, and plant some trees and vegetables. However, once the lot was cleaned, they discovered that it was not going to be that easy. The ground was rock hard from years of neglect, and people had used it to cut through the block for some time, creating well-worn foot paths. In addition, they could see the remnants of the foundation of the house that had once been there. The director of the community center called the local Clean and Beautiful commission for advice, and they suggested the forester with the State forestry agency would be able to help.

Greg, the local forester, came out to talk with the committee members in charge of establishing the park. They were in a hurry to get started because they wanted to get trees planted and the vegetable seeds in the ground before the weather got too hot. But Greg knew that he was not going to be able to solve all their problems in one morning.

Greg spent the rest of that morning walking around the property, stopping to look closely at the soil and existing vegetation, but most of all asking numerous questions. When had the house been built, and how long was it there? Was it a family residence? When was it torn down and why? Did the house have a separate garage? Where was the trash put? Did anybody remember the type of heating system it might have had? Had the property been used for anything else?

Thinking like a Farmer

You are the forester who has been asked to help these people get this vacant lot ready for planting. How would you go about doing this? Think about what you would want to know about the site, and the things that you might do to help develop the lot into the park the neighborhood wanted. Write your answers to the questions below, explaining your actions.

- What do you want to know about the property?
- Why is it helpful to know the history of the lot?
- How can you find this information?
- What specific information about the soil would you want to have and how would you go about collecting it?
- Once you have gathered all this information, what steps would you suggest the community members take to make this park a reality?
- What is the role of the community members in deciding which of your suggestions should be implemented?

After writing about the steps you would take to help these people prepare the soil for planting, read what Greg actually did.

The Rest of the Story

Looking for Clues

With as many answers to these questions as these people could provide from memory and city records, Greg decided there were several things that needed to be done, and he agreed to help them. The house had probably been built sometime in the 1920's and had been torn down about 10 years ago. He could tell where the foundation had been because of the grass growing there. But there were also areas, in addition to the compacted footpaths, in which there was no vegetation growing. One of these places he thought might be the area in which garbage and the coal ashes from the heating system in the house had been dumped. Another area that showed some evidence of a foundation was also without vegetation. He thought this might have been the garage, and that some oil and gasoline may have soaked into the ground.

The first thing he asked the committee to do was to have the soil tested for heavy metals and other contaminants. He also suggested a bulk-density test to determine the amount of soil compaction, and a core sample to see what was below the surface. He helped them get in touch with the local Cooperative Extension Service who could provide these services. Once they had all the test results, Greg was able to suggest steps to remedy the problems.

The test results showed some areas of contamination – low levels of lead, probably from paint chips around the foundation, as well as concrete washouts that raised the pH levels. The area used for trash showed a lower pH level, possibly because of coal dust in the soil. The levels of contamination were minimal, so Greg recommended removing and replacing the soil in those two locations and adding some clean topsoil.

After addressing the safety issues, Greg asked the committee members what their vision was for the park. With their suggestions, Greg proposed some ways these could best be incorporated into the existing site without too much additional work. A natural plan for the park would be to create permanent paths where the soil was so compacted that it would be difficult to restore. Trees could be planted and park benches placed where the top soil was put on top of the old foundation. After looking at the drainage pattern on the property, he suggested the vegetable garden be planted along one side, in an area that may have been a flower garden at one time. The soil analysis for pH and nutrient levels provided the committee with the information they needed for fertilizer requirements for the new trees and the vegetable garden.

With Greg's help, the park was beginning to be a reality, and Greg promised to come back in a few months to help harvest the corn and tomatoes.

Growing from the Ground Up

- What questions did you ask the committee members? Was there other information that you wanted to know that Greg did not think to ask about?
- Did you suggest the same type of soil tests and analyses Greg did? Were there other tests you thought might have been important?

- What other problems did you identify that might be found in a location such as this one?
- How similar were your recommendations for building the park to those that Greg made?

Next?

A healthy and vigorous urban forest depends in a large part on the soil in which the trees are growing. Information about these growing conditions is critical for making informed decisions about tree selection, planting, and maintenance in your community. These questions may help you make continued use of the material in this unit in your own work:

- In what ways can you use this basic information about soils to help you better identify urban soil problems in your area?

- What are some of the most difficult or critical soil problems that you know about in your community? What information from this unit and other sources can you use to help find the causes of and solutions for the problems?

- What other information sources are available to help you find out how to identify and correct urban soil problems?

- What are some of the ways you can use this information to help members of your community improve the health of urban trees?

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Checking Your Answers

Checking Your Answers about Soil

1. What are the four basic substances that make up soil?

Soil is a constantly changing mixture of four basic components:

- Inorganic materials
- Organic materials
- Air
- Water and dissolved nutrients

2. What two layers or horizons of soil chiefly influence a tree's root growth? Where are they found?

The O horizon and the A horizon are the two layers of soil that are most beneficial for a tree's growth.

- The O horizon contains the organic matter or humus that supplies the nutrients for growth and helps retain water in the soil.
- The A horizon is made up of mineral material and humus from the O layer. Most of the absorbing roots grow in this layer.

These two soil layers are not found at every site and may be arranged in different order, depending on the activity at the site. For instance, construction at a site may have removed one of the layers and changed the order of the other layers

3. How can a soil survey be helpful in an urban area?

Soil surveys can help identify the parent material of the soil. This is helpful in identifying other characteristics of the soil.

Checking Your Answers about Soil Characteristics Important for Tree Growth

1. What three things can you predict by knowing the texture of the soil? Define each of the terms you listed.

You can predict several things by knowing the texture of the soil. The texture will indicate the pore space, permeability, aeration capacity, water retention rate, and fertility of the soil. Because of the influence of texture on these soil characteristics, it is critical in selecting a species and site for planting.

- Pore space
  This is the space between soil particles through which air, water, and dissolved nutrients move. The large spaces are macropores. These are usually filled with air or are the spaces through which water drains. The small spaces that hold water and nutrients for absorption by the roots are micropores.
- Permeability
  The ease with which water moves through the soil is its permeability. Sandy soil with large pores has greater permeability than clayey soil with much smaller pores.
- Aeration
  Aeration is the process of providing oxygen in the soil for the roots to absorb. Since oxygen is carried through the macropores, a coarse-textured soil provides greater aeration of the soil then fine-textured or compacted soil, which has little oxygen available for the roots.
- Water retention rate
  The amount of water that the soil can hold is the water retention rate or holding capacity. Water is retained in the micropores for use by a tree. Fine-textured clays have more micropore spaces and thus hold more water than sandy soils.
- Fertility
  Fine-textured soils also have greater nutrient storage capacity than coarse-textured soils and are less susceptible to nutrient leaching. The smaller particles also have a greater cation exchange capacity (the ability to attract positively charged nutrients) than larger ones.

2. What makes soils fertile? What type of soil is usually the most fertile?

Soil fertility is determined by the amount of nutrients in the soil readily available to trees for growth. Soils that can attract and absorb the most positively charged nutrients are the most fertile. These nutrients include calcium, magnesium, sodium, potassium, hydrogen, and aluminum. Fine-textured, clayey soils are usually more fertile than coarse-textured, sandy soils because the fine particles are negatively charged and can attract and absorb more of the positively charged nutrients. Nitrogen is often deficient in the soil because it is negatively charged.

3. What are three reasons soil water is important for tree growth?

- It replaces water that a tree loses through transpiration. This is particularly important in hot weather.
- Nutrients necessary for growth are dissolved in soil water so they can be absorbed by the roots.
- Water stored in the soil provides a steady supply for a tree.

4. Why is knowing the pH of the soil important?

Soil pH is the measure of the acidity of the soil. Knowing the pH helps in determining the availability of nutrients in the soil and in selecting a tree for a particular location.

- First, the availability of nutrients depends on the soil pH. It is often the unavailability of nutrients, rather than the absence of them, in the soil that causes problems for trees. Many of the micronutrients needed by trees, particularly iron, are less available for absorption in alkaline soil (Harris 1992). Some nutrients, such as manganese and zinc, are insoluble in water at high pH levels, making them unavailable to trees. In acidic soils phosphorus may not be available.
- Second, each tree species has its own "best" soil pH for growth. Knowing the pH of soil helps in selecting the proper species for a site.

Checking Your Answers about the Characteristics of Urban Soil

1. What are three major problems caused by soil compaction? List two ways that compaction can be prevented and two ways to improve soil that is already compacted.

Soil compaction causes three major problems:

- Poor root penetration
- Poor soil aeration
- Low water infiltration rate

Soil compaction can be prevented in several ways:

- Find out the type of soil at the site to better understand how the soil will react to pressure.
- Cover the soil surface with a layer of mulch, no more than 4-6 inches thick, on the soil surface.
- Limit travel over the soil to designated routes.
- Work with dry or moist soils; wet soils compact more easily.
- Use light-weight maintenance equipment with large, smooth, low-pressure tires.
- Place metal grating over a planting site to keep people from walking on it.

Once soil becomes compacted, a number of options may help increase pore space and improve the quality of the soil:

- Drill small, 3-inch-deep holes for core aeration.
- Fill drilled holes with sand or peat moss to improve the texture of the soil.
- Rototill the compacted layer of soil.
- Drill holes into the hardpan (a hard layer 1 to 2 feet below the soil surface).
- Dig trenches in a bicycle-spoke pattern from the trunk of the tree and backfill with a mixture of soil and organic material.

- Mix fully composted organic mulch into the soil.
- Add mulch on top of the soil.

2. Selecting a tree species that tolerates excessive moisture is the best method for preventing problems in an area that consistently has wet soil. When excessive moisture is caused by other problems, what are three ways that it can be prevented?

Excessive soil moisture can be prevented or at least reduced through careful planting and maintenance:

- Prevent soil compaction so that water can move freely through the soil.
- Level the planting site so that there will be no low spots.
- Maintain the natural soil horizons during planting and try to eliminate debris that will change the soil texture.
- Use a coarse sand or loam soil for fill or mixing with existing soil.
- Plant the tree so that the roots are raised above the saturated soil.
- Monitor irrigation systems to make sure they are delivering only the needed amount of water.

3. When consulting with a property owner about an unhealthy tree, what are some soil conditions that you might look for or ask about?

You may already know many of the common characteristics of the soil in your area from the work that you do. However, every site has unique soil characteristics, and there are certain things that you always need to consider when determining if the soil is affecting a tree's health:

- Type of soil
- Soil texture
- Soil fertility and pH
- Amount of organic matter
- Soil temperature
- Soil compaction and causes of compaction
- Soil moisture conditions and causes of moisture conditions
- Soil drainage
- Soil contamination

These are only some of the conditions that you may ask when talking with a property owner, and you may have included others in your answer. The important point is to be aware of and consider each of the many different ways that the structure and characteristics of soil impact the growth of a tree.