# URBAN SOILS

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## ABSTRACT

Urban soil is material that has been manipulated, disturbed or transported by man's activities in the urban environment and is used as a medium for plant growth. The physical, chemical, and biological properties are generally less favorable as a rooting medium than soil found on the natural landscape. Basic soil properties are reviewed to place urban soil properties in proper context. Further, the influence of the urban environment itself imposes stressful conditions upon vegetation grown in the urban soil. To overcome potentially stressful growing conditions, urban soil characteristics must be recognized and efforts made to provide favorable conditions for plants during the design, planning and installation processes. These characteristics are explained and implications for design and operations are provided.

## INTRODUCTION TO BASIC SOIL PROPERTIES

The soil is formed as a porous medium in profile form at the interface of the earth's atmosphere and lithosphere (Figure 1). It is the result of the interaction of physical disintegration and chemical decomposition of the underlying bedrock or unconsolidated sediments placed there by long-term geologic processes. The mode of development (genesis) and resultant soil is controlled by the kind of geologic material (parent material) in which the soil forms under given climatic and vegetative conditions, modified by the effects of topography - all integrated over time (Brady, 1984). Thus, soil formation is a long-term process, and due to diversity of the soil-forming factors over the landscape, diverse soils are formed in different localities. They will have differences in their physical, chemical and biological properties. These properties determine the capabilities and limitations of a soil for plant growth. And once formed, the properties are relatively stable unless catastrophically disturbed by nature or man.

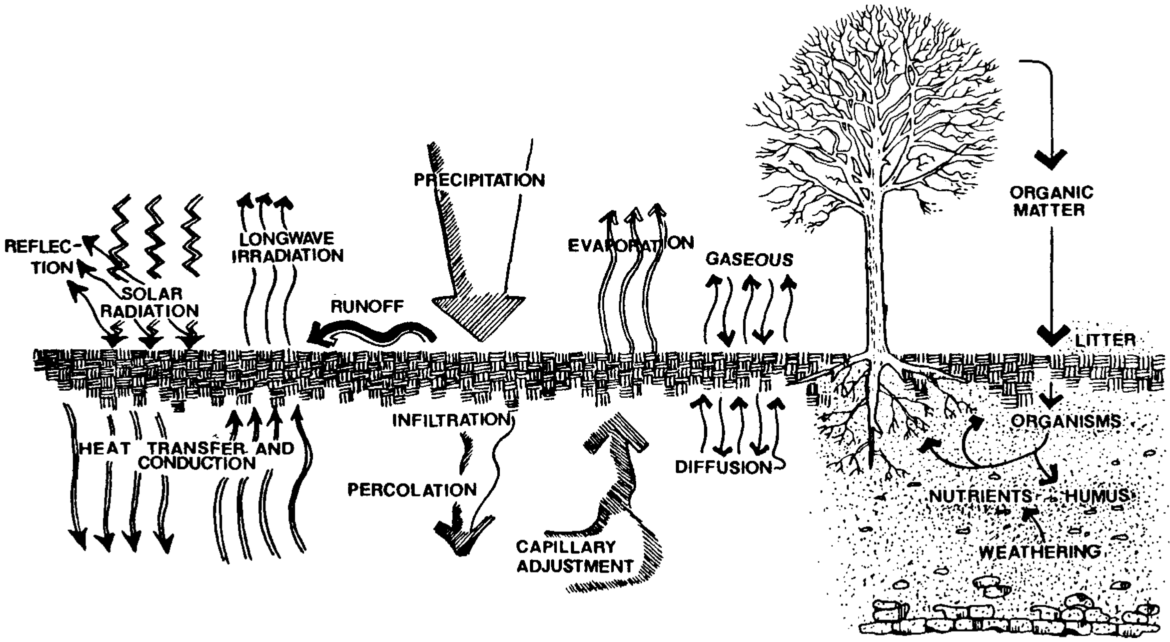


Figure 1. The soil interface between the atmosphere and lithosphere.

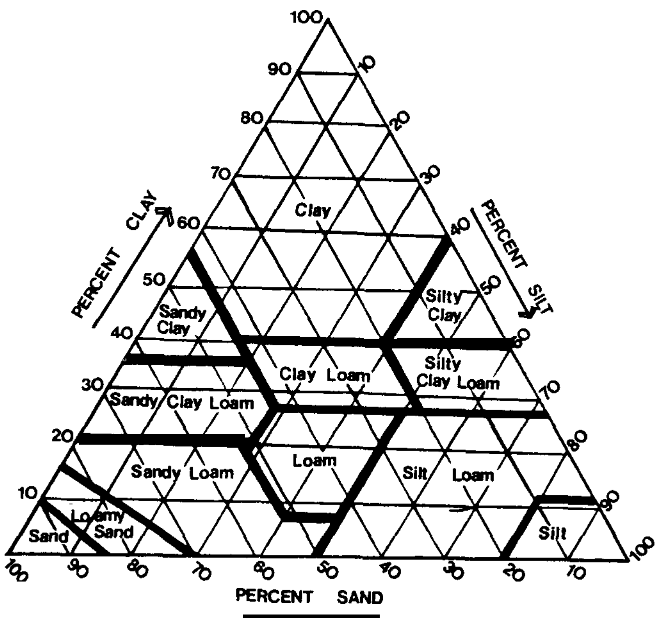


Figure 2. The texture triangle.

## Physical Properties

Soil physical properties are comprised of texture, structure, porosity and bulk density, color, temperature, aeration status and water relations. In combination, they determine such things as fertility, ease of root penetration and effective rooting depth, water permeability and retention, root growing season, and diffusion of oxygen, carbon dioxide, and other gasses.

Texture. The solid mineral material of soil is classified on the basis of diameter; thus, a sandy soil is comprised of a mixture of particles predominately of from 2 mm to 0.05 mm. A clay soil has particles that are mostly less than 0.002 mm in diameter. Water permeability is rapid for sandy soils and slow for clay soils, with silty soils intermediate. Water retention is low for sandy soils and tends to be high for silty and clayey soils. Because clay particles are chemically active as compared to the relatively inert sand and silt particles, fertility is directly related to the amount of clay in the soil. Sandy soil is generally of low fertility whereas silty and clayey soils may be of moderate to high fertility. Textural classes have been established to aid in soil evaluation, and these are illustrated in Figure 2.

Structure is the descriptive term applied to the form and degree of aggregation of the soil mineral particles. The clay particles, organic matter and other chemical compounds act as cementing agents. A soil that is highly aggregated has a well-developed structure exhibits great porosity. Aggregation ‘lightens’ the soil, enhancing root penetration, water movement, and water retention because of the wide range in pore sizes created by the aggregation. A silty or clayey soil with little or no aggregation (has mostly small pores) and will be dense (a ‘heavy’ soil). Root penetration, water movement and gaseous diffusion is restricted. These latter conditions reduce the vigor of vegetation growing on dense soil if it is not adapted to them. Sandy soils usually do not have a well-developed structure and tend to be loose, especially when dry. However, the large particles create large pores so that water movement is rapid and water retention low. The topsoil layer of most natural soils is usually well-aggregated because of high organic matter content and favorable environment for soil organism activity. The degree and type of structure changes with depth in the soil. Compaction or disturbance of the soil tends to destroy structure (reduces aggregation).

Bulk density. This is the term that expresses the relative density of a soil material including its pore space. The density of soil particles themselves is about 2.65 $Mg/m^3$. An ideal soil has a bulk density of 1.33 $Mg/m^3$, indicating that it is about 50 percent pore space. Many topsoil layers will have a bulk density near this value or less. Due to changes in texture and structure with depth, the bulk density increases with soil depth. Subsoil density values may range from 1.6 to 1.8 $Mg/m^3$. Soils with well-developed structure will have low density values (1 .I $Mg/m^3$) whereas poorly structured soils will have high bulk density values approaching 1.8 $Mg/m^3$, or greater. As bulk density increases, permeability and air exchange decrease.

Color. Soil color is the most obvious physical property in a soil profile since it varies from horizon to horizon. The topsoil is usually dark in color with brighter colors showing in the subsoil. The matrix color of a soil may be inherited from the parent material or may be indicative of the climatic conditions under which the soil formed. The developed color is influenced by the amount and degree of decomposition and incorporation of organic matter, and the amount and degree of hydration or oxidation/reduction of soil iron. The oxidation/reduction of iron is dependent upon the aeration status (oxygen concentration) of the soil. Well-drained soils have adequate diffusion of oxygen from the atmosphere into the profile and outward diffusion of carbon dioxide. This leads to oxidation of iron, which is bright red to yellowish red. Poorly drained soils have an oxygen deficiency and the iron becomes reduced as the result of anaerobic soil organism activity. The reduced iron is light yellowish brown to yellowish gray or pure gray to blue, depending upon the degree of reduction. The color modification may appear as splotches, more properly termed 'mottles', if the restricted aeration is temporary as with a fluctuating water-table. Below the water-table the gray tends to be continuous. If a watertable temporarily reaches to the soil surface, mottles will show there. This feature allows the visual evaluation of the drainage and aeration status of the soil profile, which is important for plant rooting.

Temperature. Root growth and various soil reactions are regulated by soil temperatures. Soil is heated by direct solar radiation and by heat adsorbed by the atmosphere and transferred to the soil. Biological reactions such as organic matter decomposition produce large amounts of heat within the soil. Maximum and minimum soil temperatures occur within the surface horizon and are moderated with increasing depth. In addition, there is a time lag of heat conduction both in a diurnal pattern and a seasonal one. Temperature just below the soil surface (l-2 cm) may reach 27-32° C (80-90° F) in summer. This temperature normally is optimum for root and organism activity provided moisture is available. Root and organism activity sharply decreases at 5° C (40° F) and is inhibited at temperatures above 52° C (125° F). Temperature is seldom a limiting factor in most natural soils but may become a problem in urban soils as will be shown later.

Water relations. Water retention of soils was discussed briefly under texture. In soil, there is available water and unavailable water. Available water is commonly defined as that amount of water retained in the soil between field capacity (retained against the force of gravity or about -l/IO bar) and wilting point (the water held with a force exceeding the absorbing power of the roots or -15 bars). Water may be unavailable to plant roots for several reasons. Some moves through the soil so rapidly that roots or organisms do not benefit from it. On the other hand, some water is retained with a force that is sufficient to prevent its absorption. These two conditions or states are considered unavailable water. Sandy soils have small amounts of both available and unavailable water and well-structured silty and clayey soils may have large amounts of both.

When silty and clayey soils are compacted, the amount of available water is greatly reduced. The movement (conductivity) of water is also reduced and may cause water stress in plants. A well-structured soil will have a high conductivity. The conductivity is also dependent upon the moisture content of the soil, increasing with greater moisture content. This becomes important in supplying the plant roots with adequate moisture during periods of stress such as on a summer afternoon when transpiration rate is great. If the rate of supply or the amount is insufficient to satisfy the plant's needs, the plant wilts. It should be evident that soil moisture relations and the attendant aeration status are extremely important soil physical properties that must be reckoned with in evaluating the plant growth capability of a soil.

## Chemical Properties

The chemical properties of soil include soil reaction (pH), nutrient status (total concentrations and availability to plants), cation and anion exchange capacity, and the type and amount of clay minerals present. All of these factors combine to determine the fertility of the soil.

Soil reaction. The pH is an extremely useful indicator of the soil chemical environment. It is a simple measure of the hydrogen-ion concentration of the soil solution and, though it has no real direct influence on plant growth, it is strongly correlated with other soil factors that do have significant effect. These factors include: the amount and form (available or unavailable) of plant nutrients such as calcium, magnesium, phosphorus, and iron to mention a few; the kind and level of soil organism activity including nitrification and nitrogen fixation together with organic matter decomposition. Many natural soils have a pH that may range from a low of 4.0 to a high of 8.0 or 9.0. The optimum range is 6.0 to about 7. Within this range most plant nutrients are in available form and organism activity is favored. Extremes of pH are generally deleterious for one reason or another. Soil reaction can be easily adjusted upward by liming or lowered by application of acid-forming compounds (iron sulfate sulphur) or organic matter.

Nutrient amounts and availability. Soil fertility is generally the result of inheritance from the parent material. Sandy soils are derived from sandy geologic material composed primarily of quartz which has no nutrient value; they are generally infertile. Silty and clayey soils may be derived from limestone or calcareous shales which are comprised of nutrient-containing minerals. Some of the most fertile soils are derived from limestone. Unfortunately, the total amount of a nutrient present in the soil may not be available to plants. A portion may remain as a constituent of the rock-forming minerals. Another portion may be in an insoluble form as a complex mineral or organic compound. The remaining small portion may be in water- or dilute acid-soluble form or adsorbed on clay or organic matter surfaces in an exchangeable form. For example, of the 60,000 pounds per acre of potassium that may be present in a soil, only about 600 pounds would be plant-available. Phosphorus compounds are present in small amounts in most soils and are relatively water-insoluble; at the extremes of pH they are more so. In comparison, iron is more soluble at low pH than it is at near neutral pH, but much of the iron is tied up as iron mineral constituents.

Cation and anion exchange. Positively charged ions (cations) such as calcium, magnesium, sodium, potassium and hydrogen are electrically attracted to the negatively-charged surfaces of clay and organic matter. These ions are adsorbed on the surfaces. In this form they may be replaced by other cations through an exchange process, thus creating a storehouse for nutrients available for absorption by plant roots. Because of the swarming of the cations to the colloidal surfaces, anions are attracted to the positive swarm. In this way anions, including nitrate, sulfate and phosphate ions may be involved in an exchange process as well. The greater the cation and anion exchange capacity the greater the potential soil fertility. Sandy soils have small cation exchange capacity whereas clayey soils tend to have large capacity. Organic matter has a very large cation exchange capacity and even a small organic matter content in the soil will contribute a large amount of exchange capacity.

Amount and kind of clay. From the previous discussion , it is obvious that the amount of clay in the soil determines cation exchange capacity. In addition, the type of clay also affects cation exchange capacity. There are three types of aluminosilicate clays in temperate region soils: Kaolinite, illite and montmorillonite groups. Due to differences in their crystalline structure and composition the kaolinitic group has low cation exchange capacity, illite as intermediate and the montmorillonite group has the greatest cation exchange capacity. Each soil, because of its parent material or the mode of formation, will be dominated by one type of clay or perhaps a mixture. The montmorillonite type also has the characteristic of a high degree of shrinkage and swelling upon drying and wetting. This is a distinct disadvantage in urban soils where construction is a major activity. It also reduces slope stability.

## Biological Properties

The biological properties of soil are really a commentary on the composition and activity of the soil organism population. The poulation is comprised of bacteria, algae, fungi, protozoa, nematodes, earthworms, mites, beetles, spiders, ants, centipedes and millipedes, slugs and snails, mice, moles, voles, groundhogs, and gophers. On the basis of numbers, the smaller the size of the organism, the greater the number per unit volume of soil. Not only are bacteria the most numerous but they are very important to several biochemical processes. All of the organisms are intimately interrelated as primary producers, and primary, secondary and tertiary consumers. This involves the transfer and cycling of energy, within the population as well as the larger ecosystem. Decomposition of organic matter in the form of litter on the soil surface and its subsequent incorporation in the surface soil horizon is a major result. Nutrients are released as by-products. Mineralization of nitrogen and nitrogen fixation, making nitrogen available to plants, are other important processes. As with plants, optimum moisture, temperature, aeration, pH and nutrient content are necessary for a diverse organism population and a high level of activity. Limiting conditions of any of the factors listed will limit the soil organism population and soil fertility suffers.

## The Soil Profile

As the result of the interface effect at the earth's surface the soil takes on a layered appearance (Figure 3). This is due to the gradients of moisture, temperature, aeration, and organic matter distribution in the vertical plane. The various physical and chemical properties vary accordingly. The layers are differentiated on the basis of these properties and are given formal horizon designations. Some of the horizons may be absent from certain soils.

The undisturbed forest soil has organic layers as the forest floor. They are comprised of the litter layer, fermentation layer and humus layer. These layers are obliterated upon cultivation or other surface disturbance and so are absent in agricultural or urban soils. When organic matter is incorporated into the surface mineral soil by organisms a topsoil or A horizon is formed. It is usually dark brown or nearly black in color. This horizon has the most optimum conditions for plant root growth. Leaching by organic acids causes the E horizon to form. Its degree of development depends upon the intensity of the leaching process. It may be ashy gray or not very distinct from the other colors of the profile. It may be absent or not obvious in many profiles. The B horizon is the horizon of clay and other sesqueoxide accumulation and generally has the brightest colors of the profile. The C horizon is of parent material that has not yet weathered sufficiently to be considered a pedogenic horizon. It is composed of coarsely weathered material and may be of somewhat different colors than the A and B horizons. The EB and BC horizons are transitional in nature and often may be absent.

A study of the soil profile yields much evidence as to the capabilities and limitations of the soil for plant growth and other uses. Even under the highly disturbed conditions of the urban environment, examination of the soil profile is profitable and necessary. As will be seen later, it may have an appearance totally unlike the natural soil profile.

## DEFINITION OF URBAN SOIL

Urban soils are created by the process of urbanization and therefore cannot be separated from its geographic bounds. Highly disturbed land and the

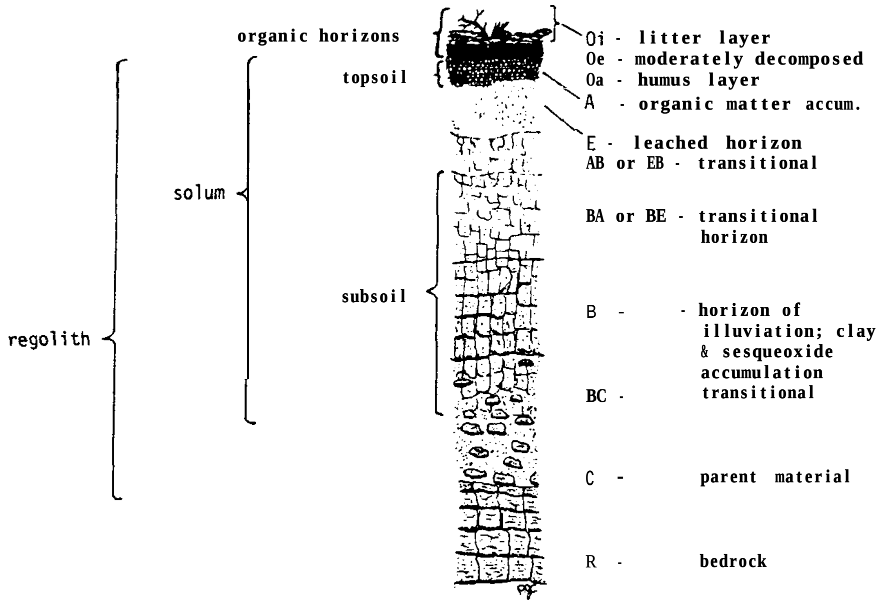


Figure 3 The idealized soil profile.

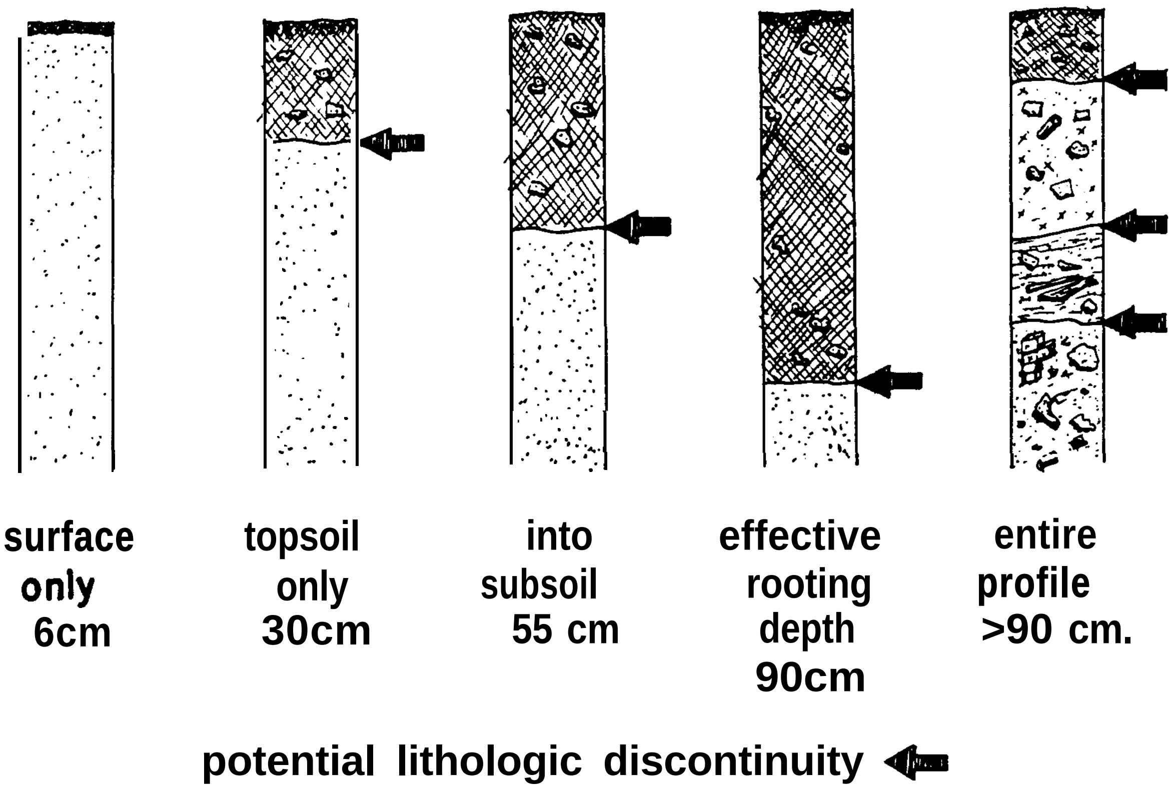


Figure 4. Various degrees of profile disturbance and accompanying lithologic discontinuities.

associated soil material does occur outside of urbanized areas, and it has similar characteristics to those found in urban areas, but the major focus here are those soils of the urban environment.

Human activity, by modification of the natural soilscape, is the predominant active agent. This is in contrast to the natural agents of wind, water, ice, gravity and heat that are the active agents in the placement of parent material within which the resultant soil-forming processes occur in the natural environment. Urbanization also contributes unique amendments and contaminants to the urban soil. Greenhouse mix or potting soil may be construed as urban soil in a broad view, but these are specialized materials and are not considered here.

Bockheim (1974) gives an appropriate and useful definition of urban soil:

> "A soil material having a non-agricultural, man-made surface layer more than 50 cm thick, that has been produced by mixing, filling, or by contamination of land surfaces in urban and suburban areas."

The inference is that the soil has been disturbed in a portion of the profile, or perhaps the entire profile may consist of fill, and that man is the primary agent of the disturbance. The mixing, filling and contamination creates a soil material that is unlike its natural counterpart. Mixing of soil material occurs when the soil is scraped away, stockpiled and respread, or it may be transported to another location and spread as topsoil. Exposure of subsoil by cutting truncates the profile which is not unlike the eroded soil found in nature. Filling refers to the process of dumping and spreading soil material, usually from diverse sources, over an existing surface. This may be done to raise it to a higher level, backfill ditches or foundation walls, or construct berms. Contamination arises from the deposition, mixing, and filling of materials in the soil not found, or at concentrations greater than those found in natural soils. The material may be anthropeic solids such as glass, wood, metal, asphalt, masonry, and plastic. Atmospheric-deposited material is included. Gasses from landfill or pipeline leaks must be considered as contaminants as well.

## CHARACTERISTICS OF URBAN SOIL

Several general characteristics of urban soils emerge. These are:

1. Great vertical and spatial variability
2. Modified soil structure leading to compaction
3. Presence of a surface crust on bare soil; usually hydrophobic
4. Modified soil reaction, usually elevated
5. Restricted aeration and water drainage
6. Interrupted nutrient cycling and modified soil organism activity
7. Presence of anthropeic materials and other contaminants
8. Modifed soil temperature regimes

## Vertical and Spatial Variability

Properties in most natural profiles gradually grade from one horizon to the next lower one, while some may exhibit abrupt changes. Urban soil profiles show abrupt changes from one layer to another depending upon the constructional history of the soil. If topsoil is scraped away and later backfilled, two distinct layers result, particularly if the topsoil is from elsewhere. The abrupt change is commonly referred to as a lithologic discontinuity (Figure 4) and an interface is created. The importance of the interface will be discussed later. This condition is common in home construction. Craul and Klein (1980) observed this layer to range from 6 to 35 cm in streetside soils. The material lying below the first discontinuity may be of the original soil profile. Each layer may drastically differ in texture, structure, organic matter content, pH and bulk density together with their related properties of aeration, drainage, water-holding capacity and fertility. One layer may be hospitable to plant root growth and survival, while the other may not. If the site has a constructional history of fill, there may be several discontinuities present, each with an interface. Therefore, great vertical variability exists which could present multiple problems for plant root growth.

Spatial variability may be just as complex as vertical variability. Superimposed upon the natural variability in soilscapes are the variation in agricultural or forest land use followed by urban constructional features of buildings, roads, mass transportation and utility networks. In a historical perspective, several cycles of change and evolution exist, depending upon the history and geographic location of the site under consideration. The influence of man is simple or complex but contributes to spatial variability in both cases. Therefore, it is not uncommon to find a drastic contrast in profiles from one tree planting pit to another on the same street within the same block. The variability is illustrated in Figure 5 (Kays, 1982), and necessitates detailed soil sampling and the production of small-scale maps.

## Structure Modification and Compaction

The development of soil structure is one of the end products of the natural soil-forming process. Aggregation of sand, silt and clay particles increases the soil bulk volume (decreases bulk density) and creates large pore spaces between the particles and between aggregates. This has favorable effects on aeration, water permeability and root penetration. One of the most important functions of wise agricultural land husbandry is the maintenance of good structure or tilth.

Most conditions present in the urban situation tend to destroy structure and prevent its formation. (Craul and Klein, 1980; Patterson, 1976). These conditions include:

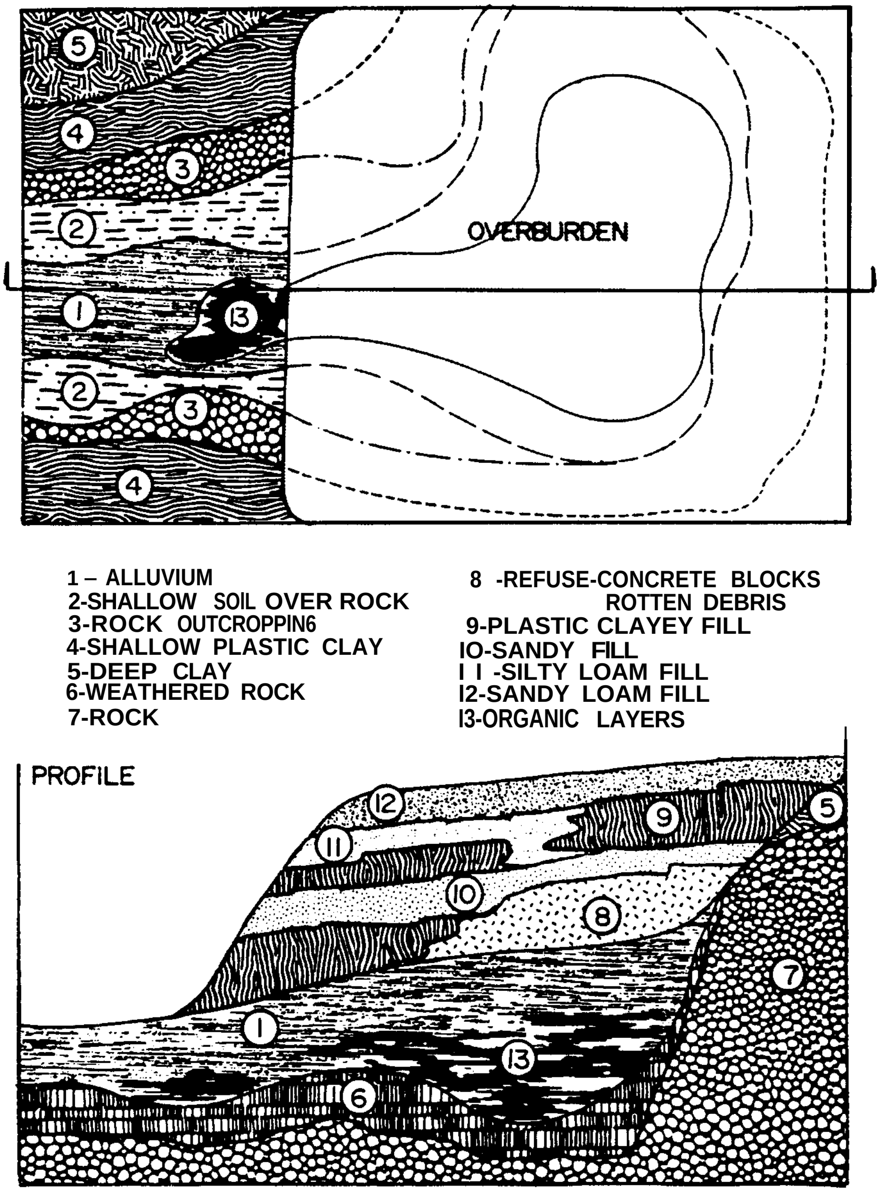


Figure 5. Spatial variability of urban soil (Kays, 1982).

1. Most urban soils have been disturbed, displaced, or compacted. This partially or totally destroying structure, reduces pore space and increases bulk density.

2. Low organic matter content which disfavors aggregation. The aggregating effect of soil organism activity is also reduced.

3. Low frequency of wet-dry or freeze-thaw cycles which enhance aggregation and structure formation.

4. Urban soils are subjected to various compressive forces over a range of moisture conditions that contribute to compaction.

5. Vegetation is subject to damage and reduction of cover, leaving the soil bare and susceptible to crust formation, compaction, and erosion.

All of these deterimentally influence other soil properties such as water infiltration and permeability, water-holding capacity, aeration status and root penetrability, especially of the upper soil layers where roots are concentrated. Poor vigor and decline in general well-being of trees and shrubs follow from the lack of water and oxygen and poor root development. Mortality is the final result under the stressful conditions of the urban environment.

Soil compaction and loss of pore space arises from forces exerted on the soil surface compressing and crushing the aggregates into smaller sizes (Patterson and Mader, 1982). Foot and vehicular traffic exert the forces. Soil with high silt or very fine sand components coupled with low organic matter content tends to naturally compact under certain moisture conditions and the presence of vibrational forces (Craul and Klein, 1980). This phenomenon is one reason for the compaction of the lower soil layers beyond the influence of surface compactive forces. Urban soils may have bulk densities that occur within the range of natural soils, but most often they are at or exceed the higher limit of the bulk density range. Patterson (1976) found average values ranging from 1.74 to 2.18 $Mg/m^3$ in four profiles of the Washington, D.C. Mall. Root penetration is highly restricted at values exceeding 1.70 $Mg/m^3$. Craul and Klein (1980) found a range of 1.54 to 1.90 $Mg/m^3$ with most centering on 1.82 $Mg/m^3$. Values from New York's Central Park (unpublished data) range from less than 1 .OO to 1.34 $Mg/m^3$ for undisturbed surface soil and 1.52 to 1.96 $Mg/m^3$ for subsoils.

It should be obvious that careful planning and incorporation of design features and maintenance to prevent or minimize the effects of compaction are necessary to provide a rooting medium that enhances the survival and growth of trees and shrubs under stressful conditions.

## Surface Crusting

A bare urban soil exhibits a pronounced tendency to form a crust on or within several centimeters of the surface. The phenomenon is caused by several factors. The most obvious one is foot and wheel traffic destroying vegetative cover and compacting the surface soil. The binding effect of roots is absent as is the surface protection provided by organic litter. The kinetic force of raindrop splash disintegrates aggregates and washes very fine particles downward, filling small pores (Hillel, 1980). A horizontal orientation of particles occurs, creating one and sometimes two distinct microlayers. Water infiltration and gaseous diffusion are reduced. A further cause, though not well-documented, is the atmospheric deposition of petroleulm-base aerosols and particulates on the soil surface. These seem to react with the soil to form hydrophobic compounds. The crust is rewetted with extreme difficulty after being dried. The effect persists until rainfall eventually 'washes' the soil.

## Modified Soil Reaction

Urban soils tend to have soil reaction (pH) values higher than their natural counterparts (Bockheim, 1974; Chinnow, 1975; Craul and Klein, 1980). Streetside soils of Syracuse, New York had a pH range of 6.6 to 9.0 with an average of about 8.0. Urban soils of Philadelphia, Pennsylvania ranged from 3.7 to 9.0 with a mean of 7.6. In Berlin, a pH of 8 was observed at streetside and less than 4 within a forest a short distance from the street.

Bockheim (1974) suggests three reasons for the elevated pH values. First, the application of calcium or sodium chloride as road and sidewalk de-icing compounds in northern latitudes. Second, irrigation of vegetation with calcium-enriched water. Thirdly, soil pH is elevated by the release of calcium from the weathering of building rubble comprised of masonry, cement, plaster, etc. (Chinnow, 1975), and the surface weathering of buildings and sidewalks under the acidic (and sometimes alkaline) atmosphere of the urban environment.

There are several disadvantages to elevated pH. Near-neutral soil reaction (pH 7) favors many processes beneficial to a wide array of plants and enhances soil fertility, but creates a soil management problem for the acid-loving plants. Also, an overabundance of calcium or sodium (or even chloride) creates an imbalance with other nutrient ions and may prevent their uptake by roots.

## Restricted Aeration and Water Drainage

Compaction of the urban soil decreases total pore space and reduces the proportion of large pores. It is within these pores that saturated water flow occurs, as does most of the gaseous diffusion of oxygen and carbon dioxide after the soil has been drained by gravity. Since water flow and gaseous diffusion are controlled by the least permeable (most compacted) horizon, even a compacted subsoil horizon may affect water movement and aeration of the entire profile. The nearer the least permeable horizon to the surface, the greater the negative influence on plant growth and vigor. A compacted surface horizon is extremely detrimental.

Covering the soil surface with impervious material cuts off water infiltration and gaseous diffusion. These processes are confined to the uncovered surface. Lateral movement of water, and especially gaseous diffusion, is limited. Therefore, a tree placed in a pit surrounded by concrete or asphalt underlain by compacted soil is supplied with very little natural precipitation in summer, followed by too much water and too little oxygen in the dormant season.

Confinement of water movement and gaseous diffusion by curbing, pipe traces, foundation walls, subway and parking garage ceilings must also be considered as being restrictive. Here again, planning, design, and maintenance operations can overcome many of the difficulties.

## Interrupted Nutrient Cycling and Modified Soil Organism Activity

The urban soil generally lacks the organic matter cycling and its nutrient contribution that typifies the soil of the natural ecosystem. Nutrient-containing (especially nitrogen, sulfur and phosphorus) leaves, litter, and animal remains are removed as wastes, or are produced in small quantities due to stressful conditions. Also, some urban soils do not rest on parent material or bedrock and do not receive the benefit of nutrients released from inorganic mineral weathering. The weathering of building rubble may be beneficial to nutrient cycling, but ion imbalance must be considered as a potential problem. Restricted vertical and lateral water movement inhibits the movement of solutes from an enriched to an impoverished area.

Organic matter is a major source of energy for most soil-inhabiting organisms. If lacking, the soil organism population is limited and the activity is reduced below natural soil levels. In fact, some components of the organism population may be absent. Because of limited moisture and aeration, it is reasonable to expect the nitrifying and nitrogen-fixing bacteria to be limited in urban soils. Without the organic horizons present, as in forest or agricultural soils, many soil invertebrates are lacking, especially earthworms, further contributing to the reduced degree of aggregation and the rate of nutrient cycling. The anaerobic conditions created by high moisture levels and reduced aeration favors fermentation bacteria which produce methane, ethane, hydrogen sulfide, nitrous oxide, fatty acids, alcohols and esters - all detrimental or toxic to most plants favored in urban design.

## Presence of Anthropeic Materials and Contaminants

During urbanization and its renewal the landscape is reshaped, filled or cut. This modification of the topography creates made land. Large portions of many large cities are built on made land (Spirn, 1984). Made land is typified by containing a high percentage of anthropeic materials (solid waste) such as masonry, wood, paper, glass, plastic, metal, asphalt and organic garbage. These materials become incidentally mixed in the soil profile and affect the physical, chemical and biological properties of the soil. The rooting volume is diluted, mechanical impedence to root penetration is created, and water-holding capacity may be reduced. The decomposition by-products, the gasses of some waste materials may be detrimental or toxic to plants and animals. Chemical by-products may potentially interfere with the nutrient cycling and uptake. Likewise, as plants suffer, soil inhabiting organisms also suffer, affecting their population levels and degree of activity. Corrosion of buried metal installations is increased by the large concentration of acids formed in landfill leachate and other anthropeic material decomposition.

Concentration of heavy metals through atmospheric deposition and decomposition by-products in the soil are additional sources of contaminants. The closer to the street, the higher the heavy metal concentration in the soil (Spirn, 1984; Brady, 1984). Spirn cites four urban situations where high lead content is likely to occur: close to city streets; areas where lead paint has washed from wooden structures; vacant lots formerly occupied by wooden structures; and garden soil amended with sewage sludge containing lead. The greatest danger is the absorption of the dust, as on a playground, or the uptake by vegetable plants, thus entering the foodchain. Direct effects on plants themselves are not well-understood.

Herbicide and pesticide residues are also contaminants in urban soils, either remaining from former agricultural operations or as residues from direct application to urban vegetation. Time and dilution help to alleviate the danger, but some persist in toxic concentration to plants and animals for many years. Having the past history of the site is important for soil contaminant evaluation, or detailed soil analyses are recommended if the history is unknown.

## Modified Temperature Regimes

It is a well-known fact that urban areas create a heat island compared to the surrounding countryside (Landsberg, 1981). Therefore, the heat loading on the urban soil is greater than that of the rural or wildland soil. The amount of heat adsorbed and reradiated by building and street surfaces is greater than vegetation, raising both daytime and nighttime air temperatures. A continuous vegetative canopy is absent and the soil is generally lacking the insulating property of an organic layer on the surface, causing the amount of radiation reaching the soil to be great. In many cases the soil is surrounded by large capacity heat-absorbing and re-radiating surfaces, increasing the heat flux to the cooler soil.

Evaporation of water from the soil surface eventually dries it and more radiation is used to raise the soil temperature, increasing the daytime maximum and imposing greater stress upon the plants. Maximum temperature on the bare, sunlit soil surface could reach a lethal level for fine roots and cambium of tender shoots. Nighttime minimum soil temperatures tend to be high because of the high air temperatures from the heat retention of structures. Plant metabolism rates potentially remain high. Few actual soil temperature data are available for urban soils, so inferences must be made from air or surface temperature measurements and heat budget evaluation at the mesoscale level, or from observation of plant response.

Soil temperature is important since it controls the growth environment of roots and soil organisms, and inorganic chemical processes. Warmer temperatures increase rates of chemical and biological processes. Root growth is extended from the fall into early winter. This may prevent hardening off of the plants in northern latitudes.

Mulching or other protection of the soil surface will do much to lower daytime maximum temperatures and prevent the drying out of the soil, benefiting fine root growth and development.

## LITERATURE CITED

Bockheim, J. G.
1974. NATURE AND PROPERTIES OF HIGHLY DISTURBED URBAN SOILS, PHILADELPHIA, PENNSYLVANIA. Paper presented before Div. S-5, Soil Sci. Soc. Am., Chicago, Illinois.

Brady, N. C.
1984. THE NATURE AND PROPERTIES OF SOIL. Macmillan Book Co., New York.

Chinnow, D.
1975. BODENVERANDERVUNGEN DURCH CARABONATE UND STREUSALZE IM WESTBERLINER STADTGEBIET. Mitt. Dtsch. Bodenkundl. Ges., 22:355-358.

Craul, P. J. and C. J. Klein.
1980. CHARACTERIZATION OF STREETSIDE SOILS OF SYRACUSE, N. Y. METRIA 3:33-l 01.

Hillel, D.
1980. FUNDAMENTALS OF SOIL PHYSICS. Academic Press, New York.

Kays, B. L.
1982. METHODOLOGY FOR ON-SITE SOIL ANALYSIS. In Craul, P. J. ed. Urban Forest Soils: A Reference Workbook. USDA Forest Service Consortium for Environmental Forestry Studies.

Landsberg, H. E.
1981. THE URBAN CLIMATE. Academic Press, New York.

Patterson, J. C.
1976. SOIL COMPACTION AND ITS EFFECTS UPON URBAN VEGETATION. Better Trees for Metropolitan Landscapes Symposium Proc. USDA Forest Serv. Gen. Tech. Rep. NE-22.

Patterson, J. C. and D. L. Mader.
1982. SOIL COMPACTION. In Craul, P. J. ed. Urban Forest Soils: A Reference Workbook. USDA Forest Service Consortium for Environmental Forestry Studies.