SOIL QUALITY – URBAN TECHNICAL NOTE No. 2

Urban Soil Compaction

United States
Department of
Agriculture

Natural
Resources
Conservation
Service

Soil Quality Institute
411 S. Donahue Dr.
Auburn, AL 36832
334-844-4741
X-177

Urban Technical
Note No. 2

March, 2000

This is the second note in a series of Soil Quality-Urban technical notes on the effects of land management on soil quality.

Introduction

Soil is a crucial component of rural and urban environments, and in both places land management is the key to soil quality. This series of technical notes examines the urban activities that cause soil degradation, and the management practices that protect the functions urban societies demand from soil. This technical note will focus on urban soil compaction.

Healthy soil includes not only the physical particles making up the soil, but also adequate pore space between the particles for the movement and storage of air and water. This is necessary for plant growth, and for a favorable environment for soil organisms to live. Compaction occurs when soil particles are pressed together, thereby reducing the amount of pore space. Examples of compaction in urban settings are traffic pans resulting from repeated trips across lots with trucks and machinery and excessive trampling by people, bicycles, etc. Soils are particularly susceptible to compaction if these activities occur when the soil is wet. The primary impacts of soil compaction are changes in the soil's physical properties (Schuler et al., 2000):

- Strength increases with compaction. Soil strength is the ability to resist penetration by an applied force and is desirable under roads and buildings.
- Bulk density increases with compaction. Bulk density is the weight of soil per volume. It is commonly reported as grams of oven dry soil per cubic centimeter.
- Porosity decreases with compaction. Porosity is the ratio of the volume of pores to the bulk volume of the soil.
- With compaction, the distribution of pores shifts toward smaller pore sizes. Pore size distribution is the array of pores, from very small to large, making up the soil's overall porosity.

  These changes influence the movement of air and water in the soil, ease of root growth, and the biological diversity and activity in the soil. For proper plant growth, void space must be available for air and water movement. Typically a medium textured soil has about 50 % solids and 50 % pore or void space. Compaction increases bulk density and reduces the number of large pores in the soil. (Schuler et al., 2000).

Compared to agricultural land, compaction in urban areas can be more permanent because of the difficulty in bringing in equipment to loosen the soil, due to the presence of utilities and the prevalence of perennial vegetation.

Causes of Soil Compaction in Urban Areas

Causes of compaction in urban areas are generally of two types:

1. Deliberate compaction during construction activities.
    - Compacting of entire areas in order to increase strength for paving and housing foundations without consideration for leaving non-constructed areas (landscaping areas and lawns) in a more natural state.
    - Use of heavy equipment for reshaping and sloping banks along roads and hillsides.
    - Grading lots and placing sod on hard soil or soil denuded of topsoil.
2. Unintentional compaction of the soil after construction is completed.
    - Allowing uncontrolled traffic (both vehicles and foot traffic)
    - Allowing vehicles on lawn areas around homes or businesses, especially when the soil is wet.

Impacts of Soil Compaction

For individual homeowners and businesses, soil compaction makes it difficult to establish and maintain lawns and landscaping due to:

- Restricted root growth.
- Reduced plant uptake of water and nutrients.
- Reduced available water capacity.
- Reduced soil biological activity.

For communities, excessive levels of soil compaction lead to environmental problems due to:

- Increased storm water runoff as a result of low infiltration rates of compacted soils.
- Increased flooding due to runoff.
- Increased erosion from construction sites.
- Increased water pollution potential, especially nitrates and phosphorus, in local rivers, streams, lakes, and ponds.

Detection of Soil Compaction

Generally compaction is a problem within the top 12 inches of the soil surface. Detection of compaction can be by:

- Observing discolored or poor plant growth.
- Probing with a firm wire (survey flag) or welding rod (18” in length) into the compacted area.
- Digging down to plant roots and finding lateral root growth with little if any penetration of compacted layers.
- Taking bulk density samples (Table 2).
- Using commercially available cone penetrometers that indicate force required to penetrate the soil in terms of pressure (pounds per square inch). Roots are unable to penetrate soil compacted to 300 psi or more. This varies with soil type and moisture content of the soil when tested (Schuler et al., 2000).

Table 2. General relationship of soil bulk density to root growth based on soil texture (NRCS Soil Quality Institute, 1999).

Soil texture	Ideal bulk densities (g/cm^3)	Bulk densities that may affect root growth (g/cm^3)	Bulk densities that restrict root growth (g/ cm^3)
Sands, loamy sands	<1.60	1.69	>1.80
Sandy loams, loams	<1.40	1.63	>1.80
Sandy clay loams, loams, clay loams	<1.40	1.60	>1.75
Silts, silt loams	<1.30	1.60	>1.75
Silt loams, silty clay loams	<1.10	1.55	>1.65
Sandy clays, silty clays, some clay loams (35-45% clay)	<1.10	1.49	>1.58
Clays (>45% clay)	<1.10	1.39	>1.47

Prevention of Urban Soil Compaction

Compaction problems during urban development can be avoided by proper planning. Working with local governments may help prevent total compaction in development areas. Divide large areas into sections to be consciously compacted for roads and foundations, and sections for lawns and landscaping. Disturb only areas needed for construction. Also, only manipulate soil when dry (less than field capacity).

Soil that will support lawns can be protected by subsoiling, and by stockpiling topsoil that will be returned to the site after construction. These two measures can restore water flow functions to near natural conditions. Establishing sod or seeding a lawn is much more successful on a loose soil with topsoil than on a compacted soil without adequate topsoil.

In parks and recreation areas, specific areas can be designated for heavy traffic (paved areas or trails). The remaining vegetated areas will benefit from less compaction because of controlled traffic. During special events, lay down metal or wood mats for better distribution of weight for vehicular traffic or involving high volume of people in concentrated areas. Mesh elements have been used for sporting fields (Beard and Sifers, 1990).

These measures may take a little more time initially, but will pay dividends in the long run. The benefits of planning and wise urban development are:

- Satisfied buyers of homes with soils that function well
- Soils that have good infiltration rates (less frequent irrigation)
- Reduced run-off (less chemical and fertilizer loss to water bodies)
- Lower mortality rates of perennial vegetation (lawns and trees)
- Better plant growth and quality for shrubs, flowers, trees, gardens, and lawns.

Management Practices for Compacted Urban Soil

Although prevention is more effective, the detrimental effects of compaction can be lessened after soils are compacted. Management practices to reduce the effects of urban compaction are:

- Subsoiling to alleviate compacted soils. Always have underground utilities and other underground plumbing or wires located and marked.
- Partial or total soil replacement. Replace dense soil with loose soil or haul in topsoil.
- Increasing organic matter. In gardens, go to residue management/no-till systems and/or cover crops.
- Use of mulch, compost, manures, and amendments.
- Annual aeration of turf grasses to improve infiltration.
- Aeration of soil using a metal tube and air compressor. This is usually used around tree roots. (Personal communication with John Lesenger. Used at the Alabama Shakespeare Festival.)
- Irrigation management. Frequent, low rates of water are necessary because compacted soil holds little water. Over-irrigation wastes water and may lead to environmental pollution from lawn chemicals, nutrients, and sediment.
- Cutting grass at higher heights, which reduces evapotranspiration losses (see local turf grass recommendations–Extension Service).

Summary

Compaction changes important physical properties of the soil. Soils with higher strength, higher bulk densities, and decreased pore space have lower infiltration rates, reduced water holding capacity, and more runoff. This degradation of soil quality results in the need for more irrigation, less healthy plants, higher plant mortality rates, and higher pollution potential from storm water runoff. Urban soil compaction is more complicated than in an agricultural setting. It is less convenient to alleviate urban compaction because soil cannot be disturbed easily around perennial vegetation, underground utilities, buildings, drive ways, etc. Planning will prevent many problems with compaction in developments and subdivisions. Preventive practices, including limiting the extent of disturbed areas, manipulating soil only when dry and restricting traffic, are more effective and less expensive than practices to alleviate compaction after it occurs. Preventing and managing compaction results in soils that function well and that benefit all of society.

References

Beard, J.B., and S.I. Sifers. 1990. Feasibility assessment of randomly oriented interlocking mesh element matrices for turfed root zones. p. 154-165. *In* R.C. Schmidt et al. (ed.) Natural and artificial playing fields: Characteristics and safety features. Amer. Soc. Testing & Materials, Standard Tech. Pub. 1073.

NRCS Soil Quality Institute. 1999. Soil quality test kit guide. United States Department of Agriculture, Agricultural Research Service and Natural Resource Conservation Service. Kit guide can be obtained at http://www.statlab.iastate.edu/survey/SQI

Schuler, R.T., W.W. Casady, and R.L. Raper. 2000. Soil compaction. Chapter 9. *In* R.C. Reeder (ed.) MWPS special publication: Conservation tillage systems and management. (In Press).