

Cooperative Extension

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Introduction

In many parts of New Jersey, there has been a transition of the landscape from agricultural and undeveloped land to one that is dominated by residential development. There is the concern that as watersheds become increasingly composed of residential development, a majority of soils there may suffer from compaction or diminished quality. Poor plant growth and compaction of these soils may result in a decrease in the infiltration of precipitation and an increase in soil erosion and runoff in the watershed. Such conditions could create or exacerbate stormwater management problems, stream erosion, and flooding.

Soil Quality and Legal Requirements

In 2011, New Jersey enacted legislation to expand current requirements for soil conservation during construction and similar activities. The new law will modify existing soil erosion and sediment control standards to include standards for soil restoration. These restoration standards would consider “optimal physical, chemical, and biological functions for specific soil types.”

Specifically, the law requires the State Soil Conservation Committee to develop new standards that land developers will need to follow to address the restoration of soil quality. At the time of writing, these standards have been developed, but still require legal review and public comment. The new standards will likely require that disturbed soils intended for vegetated areas be un-compacted and that organic matter be incorporated into these soils to improve their suitability for plant growth, if needed.

In New Jersey, Soil Conservation Plans are required for most significant land disturbance activities including development or construction. The primary responsibility for enforcing new and existing Soil Erosion and Sediment Control Standards in New Jersey is held by local Soil Conservation Districts.

The Concept of Soil Quality

The terms “soil quality” or “soil health” refer to the ability of a soil to support plant growth and deliver environmental or ecological benefits. Soil quality depends on a combination of physical aspects of the soil, such as texture, soil structure and pore space; chemical aspects such as pH and salt content; and biological aspects such as organic matter content and populations of microbes.

A soil of “high quality” is considered one that:

- can infiltrate (accept) water.
- can store water (soil water holding capacity).
- has a desirable amount of organic matter and air spaces.
- can hold nutrients for plants.
- can provide other ecosystem benefits such as filtering pollutants, limiting soil erosion, and limiting stormwater runoff.
- provides other horticultural benefits such as supporting growth of desirable plants over weeds.

Soil Quality and Stormwater Management

The properties of the soils in a watershed can have a significant effect on how the landscape handles rainfall. In many undisturbed watersheds, soils are able to infiltrate a considerable portion of rainfall. Water that infiltrates into the soil moves slowly through the soil toward groundwater or toward local streams, lakes, and springs. This has the positive effects of:

- Reduced surface runoff resulting in reduced erosion.
- Reduced peak flows in streams, which results from water taking much longer to reach the stream through subsurface flow than across the land surface or in stormwater conveyances.

- Reduction in pollutants to surface water bodies, since many pollutants in water are removed by soils as the water percolates through the soil.
- Supplying water for plant growth.
- Recharging groundwater.

Causes of Soil Degradation

While soils vary greatly in their properties and abilities to infiltrate water, remove pollutants, and support plant growth, the influence of human activity can improve or harm these soil attributes. Natural soils may take thousands of years to develop their mature physical, chemical, and biological characteristics. While good management may help return desired characteristics to moderately degraded soils, heavily degraded soils may not be easily restored. Mechanisms through which human activities can significantly degrade soils include:

- Soil compaction from human activities is common in urban, suburban, agricultural, and forest environments. Soils may be intentionally compacted during construction to enhance soil strength for supporting structures, but soil compaction is usually caused inadvertently by heavy equipment during construction or by foot and vehicle traffic on established sites. Because soil compaction reduces air spaces in the soil, the water infiltration rate and water holding capacity of the soil are reduced.
- Topsoils are sometimes stripped from construction sites and stored so that they can be returned to the site after construction. The returned soil layer will be inadequate if it is thin or the soil quality is low.
- Soil erosion, the movement of soil off site through water or wind, is possible during construction, farming, and forestry activities. Not only does soil erosion represent a loss of valuable topsoil from the site, but eroded soil particles are considered pollutants in surface water bodies, and may carry other potential pollutants, like phosphorus and some pesticides, with them.

Effects of Soil Compaction on Stormwater Management

Because compacted soils have decreased infiltration capacity, they may act as partially-impervious surfaces, especially during large rain events. Negative impacts of this include:

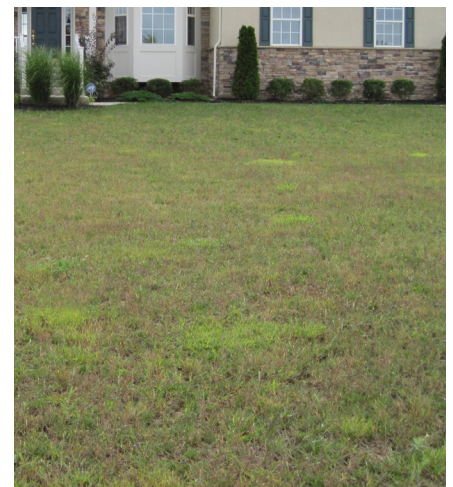
- Increased runoff, stream flows, and erosion may make flooding and sedimentation in ponds worse.
- Compacted soils will make low impact development structures—such as infiltration basins, detention basins, dry ponds, swales, and rain gardens—less effective.
- In home lawns and similar sites, compacted soils may cause water ponding, poor health of landscape plants, and surface runoff during moderate rain events or irrigation.
- The combination of poor-growing turf or groundcovers with the increased possibility of runoff can lead to increased erosion and pollutant loads to the local stormwater system and waterbodies.
- Ponding water may create mosquito habitat in some landscapes.

Landscaped Areas and Soil Compaction

Compacted soils make establishing or maintaining many turfgrasses and landscape plants difficult. Low soil aeration and low water-holding capacity may favor certain lawn and landscape weeds over desirable plants. If the soil's water



A nutrient-enriched pond in a developed area.



A home lawn with compacted and nutrient-poor soil that is dominated by weeds.



A hand-held penetrometer. The device is about 37 inches tall and has a dial on the top which reports soil strength in pounds per square inch.

holding capacity is low, more frequent irrigations may be necessary to prevent landscape plants experiencing drought stress. Plants poorly adapted to compacted soils may suffer from reduced root growth or death due to a lack of oxygen for their roots.

Because new turf areas often suffer from compacted soils, there is sometimes the perception that turfgrasses are poor at maintaining soil structure and aeration. In fact, a dense turf cover produces many roots and shoots that slow runoff, promote infiltration, prevent erosion and add organic matter to the soil. If recommended practices are followed for mowing height and irrigation frequency, turf plants will establish relatively deep root systems in good soil. Turf areas are subject to compaction, though, from foot or vehicle traffic, or from before the establishment of the turf, such as during construction. To maintain a dense turf cover, it is important to choose appropriate species for the site, follow recommended cultural, fertilizer, and irrigation practices. Using tine aeration is helpful to reduce compaction on turf areas that suffer from compacted soils.

Assessing On-Site Soil Compaction

Areas with compacted soils may be identifiable by ponding water after rainfall or sparse plant cover. Also, certain weeds occurring in turf or landscaped areas may be indicative of compacted soil conditions. These include prostrate knotweed and goosegrass, among others. But also, other common weeds such as crabgrass may be able to outcompete turf species whenever growing conditions are poor for the turf plants, including cases when the soil is significantly compacted.

Soil compaction can be measured more precisely using a penetrometer (Duiker 2002). Common penetrometers include “pocket-sized” models and hand-held upright models that allow users to stand while testing the soil. Penetrometers are designed to measure the soil strength on a scale called the “cone index.” The ability of roots to penetrate the soil decreases with increasing cone index values, with 300 pounds per square inch being a commonly cited limit above which root penetration is minimal. When using a penetrometer, be sure the soil is moist in order to get an accurate measurement.

Soil Infiltration Capacity

The infiltration capacity of a soil is a measure of the rate at which a soil can take in precipitation or applied irrigation. Any excess of this rate is liable to cause water to pond or create surface runoff. The infiltration capacity of a given soil varies with the conditions of the soil: for example, a soil may have a higher infiltration capacity when dry than when already thoroughly wetted.

A soil’s infiltration capacity can be decreased by compaction or increased over time by additions of amendments and biological activity.

A soil’s ability to conduct water may decrease below the surface, particularly if there is a subsurface compacted layer from human activity or a natural dense layer. A single type of soil may exhibit variability in infiltration capacity over a small area since infiltration may be increased in localized macropores, like worm holes, animal boroughs, cavities from roots, or cracks in the soil structure.

Infiltration capacity is usually measured with a double-ring infiltrometer, but there are variations in the way it is measured. Because of this, readers should use some caution interpreting reported results for infiltration capacity.

There is no standard classification of infiltration capacity rates into high or low categories. Instead, a soil’s infiltration capacity should be judged relative to its natural physical properties and its uses in the watershed. One approach to judge a soil’s infiltration capacity is to consider how it would behave during a “design storm” for New Jersey, which is used in assessing the effectiveness of stormwater management practices (NJDEP 2004). A design storm is a hypothetical rain event based on rainfall patterns typical in New Jersey. During the most intense part of this storm, 0.75 inches fall in 20 minutes, yielding a precipitation rate during this period of 2.25 inches per hour. Using this value, a soil with an infiltration capacity of 2 inches per hour or greater would be considered pervious for most rain events in New Jersey. It should be taken into consideration, though, if a permeable area such as a lawn, swale, or basin is expected to infiltrate not only precipitation that falls directly on it, but also water diverted from impervious areas such as roofs or driveways.

Determining the Extent of the Problem in Residential Areas

Because assessing infiltration capacity, soil density, and subsurface compaction of soils in residential areas is relatively time consuming, scientific studies tend to sample relatively few properties. These studies tend to find a wide range of soil properties, for example with infiltration capacity ranging from close to zero to several inches per hour (Hamilton and Waddington 1999, OCSCD 2001, Mueller and Thompson 2009, Woltemede 2010). Different studies are conducted in different parts of the U.S., with different native soil conditions, making generalizations difficult.

These studies do suggest, though, that soil compaction or degradation is relatively common in residential areas.

Even with natural differences in soil texture and structure in a given area, the effects of disturbance during development and compaction are evident. Some studies suggest that more newly-developed areas may have more impacted soils. This might be explained either because the action of roots and weather has ameliorated impacts in older areas, or because new construction techniques may impact soils more intensely.

Natural Variations in Soils

When considering the concept of soil health, it is important to note that there is a wide natural range in soil properties. Soils which are naturally very clayey may have low water infiltration capacities unless they are amended with organic materials and managed to promote the soil being well-structured. Naturally sandy soils may have a high infiltration capacity but a lower ability to store water or remove pollutants from water. Silty soils may be naturally prone to erosion. Other soils may have naturally low organic matter or be shallow to bedrock. It is important in some cases to understand the natural limits of certain soils, and to realize that not all soils—even when undisturbed—will perform all the horticultural and ecosystem services that may be desired in a given situation.

Preventing and Alleviating Soil Compaction in Residential Settings

Some practices that can be followed by residents or those working in a home, garden or, landscape setting to prevent soil compaction include:

- Avoid foot and vehicle traffic on wet soils, particularly if soils are fine textured, “heavy”, or clayey. Wait until the soil has dried before driving or walking on it.
- Limit the areas subjected to heavy foot and vehicle traffic. Use designated drive lanes or garden paths. Covers like stone, mulch, or pavers can be used to direct traffic and reduce soil compaction.
- Have the chemical and physical properties of the soil tested.
 - A basic fertility test at the Rutgers Soil Testing Laboratory will provide information about the pH and nutrient levels in the soil. The Laboratory will provide lime and fertilizer recommendations for specific plants being grown. Clayey soils with low calcium levels can suffer from poor soil structure, resulting in a soil with insufficient pore spaces to hold plant-available water or air for plant roots. If the calcium levels are below optimum, the soil should be amended with lime

or gypsum according to soil test recommendations. Alternately, one recommendation is to apply gypsum at a rate of 20 to 45 pounds per thousand square-feet in order to raise calcium levels without raising soil pH (Heckman 2003b).

- An additional test available from the Soil Testing Laboratory that includes soil texture, organic matter, and soluble salts may be helpful for problem soils.
 - ▶ Soil texture varies naturally from very sandy soils to very clayey soils. Sandy loam, loam, and silt loam textures, however, may be the most desirable for topsoils (Heckman 2003a). The texture of a soil is a result of the proportions of different-sized mineral particles in the soil—the percentages of sand, silt, and clay particles. Soil texture is typically a fixed property of the soil; it cannot be changed with any practical method.
 - ▶ Organic matter also varies naturally in soils, and some soils may have naturally low organic matter contents. What soil organic matter content is considered desirable depends upon the texture of the soil. While an organic matter content greater than 2.0% may be considered good for a sandy loam soil, a silt loam soil with greater than 4.0% may be considered good (Rutgers STL, no date). Raising a soil’s organic matter content is often valuable for improving soil quality. Additions of organic matter are particularly helpful on both sandy and clayey soils, since the addition of organic material improves soil structure resulting in a soil that behaves more like a loam soil. Organic matter sources, like compost, should be incorporated into soils when possible. Soil organic matter can also be increased over time by establishing a perennial vegetative cover like turfgrass.
 - ▶ Soluble salts may be a problem in soils receiving high amounts of fertilizers or certain organic amendments that are high in salts. The amount of soluble salts is typically determined by measuring the electrical conductivity of a water extract of the soil. The sensitivity to salts varies greatly by the type of plant grown, and also the age of the plant, with seedlings and transplanted plants being more sensitive. For a “1:2” extract (1 part soil to 2 parts water), 0.5 to 2.0 mmhos/cm is the range in which plants become negatively impacted (Rutgers STL, no date b). Values above this range may be detrimental to plants.

- Aerate established turf and landscape areas with a tine aerator that removes cores of soil.
- Consider “subsoiling,” which is tilling or using other mechanical means to break up compacted soils several inches below the surface. Commercial machines used in the landscape industry are capable of cultivating soil to a depth of 8 to 10 inches (20 or 25 cm), while removing stones and rolling the soil bed for seeding. It has also been suggested that using a backhoe to lift and loosen soil can also relieve compaction (Heckman 2010).
- For areas like gardens or raised beds, the importation of additional or replacement topsoil may be practical if other solutions are not successful (Heckman 2003a). Particularly if the source of the imported soil is not known, it should be tested for lead contamination (Hamel et al. 2010). Lead is not the only potential contaminant of concern, but testing for a wide range of contaminants can be prohibitively expensive for a homeowner.

Treating soil compaction may be difficult in urban or suburban areas because it may be difficult to get equipment into small lots, there may be buried utility lines, and there may be significant perennial vegetation like trees (NRCS 2000).

Preventing Soil Compaction During Construction

The degree of soil compaction capable with heavy construction equipment can limit the root growth of landscape plants. Practically speaking, deep and heavy compaction may be permanent if the soil structure is largely destroyed.

Practices occurring during construction activities that may lead to compacted or degraded soils include:

- clearing large areas.
- excessive traffic from heavy construction equipment or using heavy equipment on moist soils prone to compaction.
- the movement of wet soils—particularly fine textured, “heavy”, or clayey soils—with equipment.
- soil left bare for long periods of time and subjected to erosion.
- removal of good native topsoil and replacing it with a thin layer of topsoil or with low-quality soil.

Practices occurring during construction activities that may prevent compacting or degrading soils include:

- use of travel lanes for equipment so that less area of the site is compacted.
- retaining topsoil or replacing stripped top soil with a high-quality soil of sufficient depth.
- stabilizing areas subject to erosion, such as slopes or erodible soils.
- use of berms, erosion control blankets, and silt fences to contain eroded sediment onsite.
- establishment of vegetative cover on soils as soon as possible.

Beginning with soils that are compacted, of low pH or low fertility may make establishing most turf species or other landscape plants extremely difficult. Furthermore, some inexpensive “contractor’s mixes” of turf seed may predominantly contain turfgrass species that do not grow well under the conditions of the site or may use inferior varieties. Mixes with a high proportion of annual ryegrass (*Lolium perenne* ssp. *multiflorum*) may not produce lasting vegetative cover. While this grass germinates and provides vegetative cover quickly, it may not survive well in either cold winters or hot dry summers in New Jersey (PLANTS 2010).



Commercial equipment capable of tilling a home lawn area.



Graded soil in a home lawn area during lawn renovation.

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