Article 37

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Can Urban Soil Compaction Be Reversed?

Soil compaction appears to be an inevitable result of current construction practices (see article 36). The key question is whether it is possible to reverse soil compaction. Numerous soil scientists have evaluated practices that can avoid compaction during construction or reverse it after it occurs (Table 1). These practices include selective grading, special construction equipment, reforestation, mechanical loosening, and the use of soil amendments. This note reviews what is currently known about how well these practices work and evaluates their potential as a stormwater management strategy in urban watersheds. The consensus among soil scientists is that alleviating urban soil compaction is a very hard job. Indeed, Randrup (1998) notes that once a soil is compacted, it is extremely difficult to restore its original structure, particularly if the compaction extends several feet below the surface.

Techniques to Avoid Compaction During Construction

The traditional remedy for soil compaction has been to require contractors to loosen soil by tillage, ripping or other techniques before lawns are established (much as a farmer plows a field). However, Randrup (1998) could find no significant difference in soil bulk density between Danish construction sites that had been loosened and those that had not. Similarly, Paterson and Bates (1994) found that tilling resulted in only a minor improvement in compaction in urban soils in Washington, D.C. (see Table 1).

Another common technique for avoiding soil compaction is the practice of selective grading, where only the most critical portions of the site are mass graded, and the remainder of the site is cleared but not graded. Again, neither Randrup (1998) nor Lichter and Lindsay (1994) were able to detect any improvement in soil bulk density in the selectively graded construction sites. These soils still experienced extensive compaction by construction equipment, stockpiling and vehicle traffic. The only soils where compaction was prevented were areas that were fenced to exclude all construction activity.

In the past several decades, specialized equipment has been developed to minimize compaction (e.g., terralifts, and subsoil excavators). Rolf (1994) detected a modest improvement in bulk density (0.05 to 0.15 gm/cc) when this specialized equipment was used at several Swedish construction sites, compared to traditional construction equipment. Even so, the specialized construction equipment still resulted in soil compaction at the site. Based on current research, it appears that the best construction techniques are only capable of preventing about a third of the expected increase in bulk density during construction.

Table 1: Reported Activities That Restore or Decrease Soil Bulk Density

Land Use or Activity	Decrease in Bulk Density (gms/cc)	Source:
Tilling of Soil	0.00 to 0.02	Randrup, 1998, Patterson and Bates, 1994
Specialized Soil Loosening	0.05 to 0.15	Rolf, 1998
Selective Grading	0.00	Randrup, 1998 and Lichter and Lindsey, 1994
Soil Amendments	0.17	Patterson and Bates, 1994
Compost Amendment	0.25 to 0.35	Kolsti *et al.*, 1995
Time	0.20	Legg *et al.*, 1996
Reforestation	0.25 to 0.35	Article 36

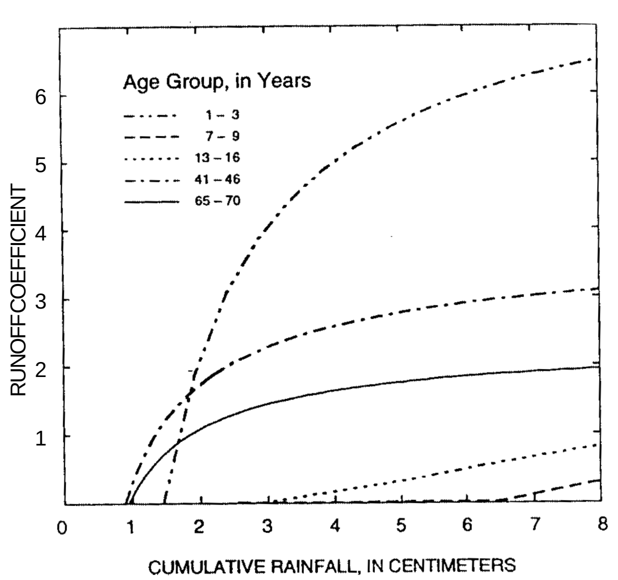

Figure 1: Cumulative Rainfall Versus Runoff Coefficients for Different Lawn Age Groups

Further, it is evident that the only truly effective technique for avoiding compaction is prevention, i.e., setting limits of disturbance that are capable of physically excluding all construction traffic from portions of a site.

Techniques to Reverse Soil Compaction After Construction

Once soil is compacted, is there anything that can be done to reverse the process? Many natural processes act to loosen up soil, such as freezing/thawing, particle sorting, earth worm activity, root penetration and the gradual buildup of organic matter. Often, however, these processes take decades to work, and operate primarily within the first foot or so of soil. In addition, many of these natural processes are effectively turned off when soil compaction becomes severe (i.e., bulk density greater than 1.7) because water, plant roots and soil fauna simply cannot penetrate the dense soil matrix and get to work.

There is some evidence that the bulk density of residential lawn soils does gradually recover over several decades. Legg *et al.* (1996) monitored the soil and runoff properties of 20 residential lawns in Madison, Wisconsin that ranged in age from one to 70 years. They found that newly established lawns (less than three years old) had the highest bulk density and lowest organic matter content of all the lawns sampled. Subsequent analysis indicated that these younger lawns produced significantly more runoff than their older counterparts (Figure 1). As lawns grew older, bulk density declined modestly and the amount of organic matter increased in the first foot of the soil profile. It was speculated that root penetration, earthworms, and general soil building created more macro pores, and contributed to the improvement in bulk density and soil quality over time.

Another long-term approach for restoring compacted urban soils is reforestation. Trees and shrubs gradually build soil structure through root penetration, leaf fall, macro pores and associated soil fauna. However, this process may take decades to occur, and usually requires a helping hand in urban watersheds. For example, establishing trees in compacted urban soils often requires the excavation of larger and deeper tree pits filled with special soil mixes to allow tree roots to flourish.

Soil Restoration Through Soil Amendments

A quicker technique for reducing soil compaction involves amending the soil with organic matter that has a low bulk density, such as compost, fly ash, or peat. Patterson and Bates (1994) found that amendments of sintered fly ash were able to decrease bulk density by 0.17 gms/cc over a 22-year period on soil test plots on the heavily used Mall in Washington, D.C. Other researchers have reported decreases in bulk density of as much as 0.30 gms/cc when compost was incorporated into glacial till soils in the Pacific Northwest (Kolsti *et al.*, 1995). Clearly, the compost amendment technique shows promise in reducing compaction in urban soils, and has recently received a great deal of attention as a potential practice for reducing stormwater runoff problems at the site level. Much of the work in this area has been conducted in the Pacific Northwest, and is focused on incorporating compost amendments for new or existing residential lawns.

The compost amendment practice is fairly simple, and is best started in the very early spring or early fall, during relative dry conditions. For an existing lawn, it begins with a soil test to determine existing bulk density for the yard. If the test indicates that soils are compacted, the next step involves deep tillage of at least the top foot of soil, using a rototiller or ripper. After the sod has had a few months to decompose, compost is incorporated into the soil at the volumetric ratio of one part compost to two parts loose soil (or three to four inches over the lawn). As a rule of thumb, about ten cubic yards of compost are needed per 1,000 square feet of lawn that is amended.

Helpful specifications on determining the proper amount of compost are provided in Chollak and Rosenfeld (1998), as well as guidance on selecting compost of the right source and age. It may also be necessary to add dolomitic lime at a rate 100 lbs/1,000 square feet to control acidity. After compost amendment, grass is then reestablished by seeding or sodding. The process for amending compost into new lawns is slightly different; more detailed information can be found in Chollak and Rosenfeld (1998) and McDonald (1999).

While compost amendment seems like an ideal practice, there are a number of situations where it is not feasible. These include sites that have steep slopes, a high water table, wet saturated soils, or downhill slope toward the house foundation (these areas are usually are poor candidates for a traditional lawns, as well). In addition, deep tillage within three feet of the drip line of trees and shrubs should be avoided.

The cost to install a compost amended lawn on a new residential lawn is about 72 cents per square foot, according to Chollak and Rosenfeld (1998), but can drop to 66 cents per square foot if applied across all the lawns in a new subdivision. For a typical quarter-acre lawn, the cost of installing a compost-amended lawn is about $7,200, including labor, equipment rental, compost and hydro-seeding. This is about twice the cost of traditional methods to establish a new lawn (Chollak and Rosenfeld, 1998). However, the cost of compost amendment drops to about 20 cents per square foot if labor is excluded (assuming compost is available at $12/cy, delivered, rental of tiller/spreader, soil test, lime and grass seed). Thus, if a homeowner were to do it himself, the cost of amending an existing quarter acre lawn might run about $2,200, with the time investment of two or three weekends.

A faster and less costly compost amendment practice has been recently introduced in the Pacific Northwest. It involves aeration of existing soil (but not deep tillage), followed by the placement of about three inches of compost over the surface of the lawn in the fall. The lawn is then seeded in the spring. Initial results indicate that this simplified practice produces good turf, but the hydrologic benefits have yet to be quantified. If future monitoring indicates that this simplified practice works, it will sharply reduce the costs and effort for the individual homeowner to restore his or her yard.

Benefits of Soil Compost Amendments

A number of recent research studies have explored the potential hydrologic benefits of compost-amended soils. Kolsti *et al.* (1995) monitored test plots of amended and unamended soils over ten storm events in Seattle, and reported that compost-amended soils reduced surface runoff by 29 to 50%, depending on the amount and type of compost used. Even higher reductions in lawn runoff (53 to 74%) were predicted if compost amendments were implemented across a small watershed, according to a model developed by Hieliema (1999). Chollak and Rosenfeld (1998) estimated that stormwater detention basin volumes could be reduced by five to 15% if compost amendments were incorporated into new subdivisions in glacial tills soils near Seattle, Washington.

Compost amendment can also provide benefits for the lawn owner. For example, compost-amended lawns generally have a fraction of the summertime irrigation needs of a normal lawn. In addition, the organic matter in compost supplies meets all of the lawn's fertilization needs, at least for the first year (Landschoot, 1996). Grass also appears to grow better on compost-amended soils. Indeed, researchers have reported that compost-amended lawns exhibit more rapid turf coverage, denser root networks, greater rooting depths, lower bulk density and higher organic matter (Harrison *et al.*, 1996 and Kolsti *et al.*, 1995).

Compost Amendments as a Stormwater Management Strategy

The compost amendment practice should be considered an element of better site design, and could be a useful technique to reduce stormwater at the residential lot level. It is likely that its benefits would be amplified in conjunction with lawns also designed to treat rooftop, driveway and sidewalk runoff. Several creative designs to integrate compost amendments with other on-site practices in residential areas are described in Konrad *et al*. (1995). Compost amendments could also be used to improve the performance of grass swales, biofilters and filter strips. Communities may want to encourage developers to install compost amendments during new lawn and landscape construction (possibly through stormwater credits).

Compost amendments might also prove to be an effective tool for watershed restoration, particularly in watersheds where other stormwater retrofit options are not feasible. The cumulative hydrological benefits of restoring soil quality on hundreds of lawns, athletic fields, and vacant lots could potentially be significant. The critical management issue is determining how to deliver lawn and landscape compost amendment services to homeowners in a cost-effective manner across an entire watershed. Communities may need to make free compost and technical assistance available to achieve wider restoration of compacted soils in the urban landscape.

Summary

While the initial research on compost amended soils is promising, more research and demonstration are needed to more precisely define the stormwater management benefits of the practice. In particular, paired monitoring of the runoff and pollutant load from amended and unamended lawns should be a high priority. Further long term research is also needed to determine how long the benefits of compost amendments persist. For example, are compost amendments only needed once, or must they be repeated as the compost decomposes? What kind of lawn maintenance practices are needed to maintain the benefits of amended lawns? How should the compost amendment practice be adapted to suit conditions in other climatic regions of the country?

Still, perhaps the greatest property of compost amendment is its potential to develop into a true homeowner management practice, particularly if a more simplified version can be developed. A homeowner gets the benefit of a better yard, and possibly a better watershed, for simply changing how he or she invests in lawn practices. ***–TRS***

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