SOIL AMELIORATION TREATMENTS FOR URBAN AND COMMUNITY LANDSCAPE SITES

George R. Otoko
Civil Engineering Department,
Rivers State University of Science and Technology,
Port Harcourt.

Isotem Fubara-Manuel
Agricultural and Environmental Engineering Department,
Rivers State University of Science and Technology,
Port Harcourt.

Abstract
Plant establishment and growth is the beauty of urban and community landscape sites; but compacted soil is a frequently encountered problem on such sites. Numerous site amelioration methods and planting techniques have been employed to counteract the harmful effects of soil compaction on such sites. No doubt, compaction restricts woody plant growth, but the nature and causes of the restriction are not completely understood. Consequently, techniques to improve compacted soil condition for landscape trees cannot be prescribed with confidence.
Therefore from the perspective of woody plant establishment, this paper presents a review of soil compaction and its amelioration.

Introduction
Woody plant establishment are the beauty of urban and community landscape sites. Unfortunately, growing trees successfully in the modern urban environment is extremely problematic. Mostly, the trees do not survive the first two years and the average street tree life span in city neighbourhoods has been estimated to be only ten years (Foster and Blaine 1978); reason for the poor survival rate being the adverse rooting environment provided by many urban sites (Craul 1985). Landscape plantings are usually around buildings, especially newly constructed ones, where underlying soils are often mixed and compacted by construction traffic and covered with top soil (Alberty et al 1984).

COMPACTION AROUND NEW CONSTRUCTION
Limited rooting space, compaction, aeration, poor drainage are some of the problems of urban sites (Craul 1985), as shown in figure 1. Around new construction sites, record often extreme compaction levels. Patterson in his study, found the park's clayey soil in Washington D.C to be extremely compacted with bulk densities from 1.7 to 2.2 g/cm^3 (Patterson 1977). Similar levels of densities were recorded by Alberty 1984 in a survey of area to be landscaped near new residential and commercial construction; infact, even showing an increase of about 0.5g/cm^3 over adjacent undisturbed areas. Such levels of compaction restrict root growth for many woody species (Chiapperini et al 1978; Pan and Bassuk 1985 and Zea et al 1980).

Figure 1: Part of Greater Port Harcourt Housing Construction Site, Nigeria.

ROOT GROWTH IN COMPACTED SOIL

Root growth in compacted soil is usually adversely affected, resulting in increased branching and radial thickening of roots (Malerechera et al 1991). Compaction also appears to decrease tree establishment, as roots are unable to penetrate dense soils encountered beyond the planting hole. (Foil and Ralston 1967; Youngberg (1969). This dramatically also reduces shoot growth (Chiapperini et al 1978), and is indicated as a primary factor in sugar maple decline in Urban areas (Ruark et la 1983). Compaction level is generally characterized by soil bulk density or by resistance to penetration as determined with a penetrometer. However, there appears to be some variation among species in their ability to penetrate compacted soil of a given bulk density (Pan and Bassuk 1985). As such, some have suggested making adjustment to critical bulk densities based on soil texture (Ruark et al 1982; Veihmeyer and Hendrickson 1948), with sandier soils having a higher critical bulk density for root growth than finer textured soils, although not quite yet experimentally developed. As such, it is difficult to use bulk density as a predictor of plant response; instead, penetrometer measurements have been extensively used. However the resistance encountered, varies with the penetration cone design, application of lubrication and method of forcing into the soil (Voorhees et al 1975); all of which difficulties can be overcome by equipment standardization. Since the late 1960's, the American Society of Agriculture Engineers has had standard in place for penetrometer design in terms of cone inclination and diameter sizes (American Society of Engineers 1992). Penetrometer resistance has been made strongly correlated to plant performance than bulk density (Taylor and Gardner 1964 ; Thompson et al 1987). Unless moisture levels are constant, measurements must be taken over a range of moisture levels, as a clay soil that is completely impenetrable when dry can be very easily penetrated when saturated.

For row crops, a resistance of 2 MPa could be restricting to plant growth (Materechera et al 1991). However removal of topsoil and consequently low nutrient availability may also contribute to growth reduction (Neumann 1987).

SHOOT GROWTH IN COMPACTED SOIL

Soil compaction also adversely affect shoot growth (Alberty et al 1984; Chiapperini et al 1978; Pan and Bassuk 1985). This means that the small volume in soil exploited by roots would result in a small water reservoir available to the plant. However some studies, indicate that the effect of root restriction on shoot growth is independent of water supply (Krizek et al 1985; Mc Connaughay and Bassaz 1991). However, water uptake and compaction relations merit further study.

Krizek and Dubik 1987 has suggested that shoot reduction in response to mechanical impedance could be a result of an alteration in the production of root-synthesized hormones, even though there is no experimental evidence. An increase in ethylene production has been demonstrated in roots encountering mechanical impedance; which increased root diameter in beans, with no effects on shoot growth (Kays et al 1974); but with effects on rooted cuttings by preventing bud break in roses (Sun and Bassuk 1993); and with effects also, on maize (Tardieu et al 1991).

SOIL AERATION AS A RESULT OF COMPACTED SOIL

Poor aeration can result from compacted soil, as macropores are compressed, resulting in a larger volume of micropores through which air and water move slowly (Hillel 1982). Low soil air oxygen levels restrict root growth (Erickson 1982; Valoras et al 1964; Yelenosky 1964). Plant response to oxygen level, however, has been shown to interact with mechanical impendence (Gill and Miller 1956). As such, the critical oxygen level in compacted soils may be higher than in uncompacted soils (Tackett and Pearson 1964). Limiting oxygen levels are of particular concern when considering compacted soils for planting. Soil compaction limits gas exchange and may contribute to poor soil aeration. Flooding and poor drainage can also restrict gas exchange. These limitations to aeration may be exacerbated by increased oxygen consumption by roots and microbes during the growth season (Yelenosky 1963). Oxygen diffuses approximately 10,000 times more slowly through water than through air (Nobel 1991). As such, oxygen may be limiting when soil pores are filled with water (Currie 1984). Soil compaction alone may not produce limiting oxygen levels, if drainage is adequate (Taylor and Burnett 1964; Boynton and Reuther 1938; Yelenosky 1964). With adequate drainage oxygen apparently diffuses to a significant depth through dense soils. As such, although gas exchange may be slow in compacted soils, oxygen levels considered detrimental to root growth may not necessary result.

OTHER INFLUENCING FACTORS

Soil compaction can also limit other factors such as gas exchange, surface and subsurface drainage. Water drainage depends on soil permeability and permeability depends on degree of compaction. Surface crusting can restrict water infiltration and then increase runoff. Poor soil structure brought about by compaction slows water movement through the soil profile. These two factors acting together may allow water to collect in the bottom of a planting hole dug in compacted soil, thus flooding tree roots (Watson 1988).

Another aspect of the relationship between compaction and water drainage is the decrease in soil strength resulting from an increase in soil moisture (Taylor and Burnett 1964). There can be a critical soil strength above which woody plant roots will likely be greatly restricted (Day 1993). Soil moisture must therefore affect root restriction in some soils via its effect on soil strength.

Slower water drainage through compacted soils may show the leaching of road salt (Ruarh et al 1983); which itself disperses soil aggregates (Brady 1990), thus contributing to soil compaction.

AMELIORATIVE MEASURES FOR COMPACTED SOIL

Three major categories of techniques may be used to ameliorate compacted soil or alleviate its associated stresses & they are (i) remedial treatments around existing trees. (ii) treatments to reduce further compaction. (iii) methods to alleviate soil compaction before planting.

REMEDIAL TREATMENTS AROUND EXISTING TREES

Compaction remedial efforts focusing on improving soil aeration have been developed since the 1920's, but none of the methods affected bulk density (Smiley et al 1990). Drainage mats placed vertically in a clay loam soil to act as aeration panels acted one day after irrigation (Lindsey and Bassuk 1993). After two days, however, this effect had dissipated. Two years after remedial treatments intend to alleviate compaction strength were installed, no differences in shoot growth were found (Pillenger and Stamen 1990).

Digging trenches in dense subsoil and filling them with loose soil, rooting depth of cotton planted on top of the trench increased as roots took advantage of the looser soil below (Heilman and Gonzalez 1973).

TREATMENTS TO REDUCE FURTHER COMPACTION

Extremely compacted soil may be difficult to avoid where extensive foot or other traffic is expected. Heavily trafficked picnic area was examined by Patterson (Patterson 1977). Fly ash and expanded slate amendments resulted in lower bulk densities for up to four years, and integrity of the materials partially maintained after four years of heavy traffic. The effects of these amendments on other soil properties and on plant growth are yet to be fully understood.

METHODS TO ALLEVIATE SOIL COMPACTION BEFORE PLANTING

For moody plants, soil preparation is an option only where there are no existing trees or shrubs, because it involves subsoiling and tillage techniques. So, the long term effects of deep tillage on soil strength and bulk density are critically important. Subsoiling compacted clay loam soil reduces soil strength (Johnson et al 1987). Subsoiling of a sandy loam soil initially lowered soil strength and increased potato yields, but two years later, the original strength was almost restored by tillage, and a yield effect was no more (Bishop and Grimes 1978). It therefore appears that the effect of deep tillage on soil compaction is short term considering the expected lifetime of a woody plant landscape.

Backfilling the planting hole with peats or other material in order to relieve general transplanting stress, does not work in compacted soil (Ingram et al 1981). Hummel found no differences in shoot and root growth between container grown trees planted into sandy soil with peat-amended backfill and those planted into sandy soil with peat-amended backfill and those backfilled with native soil (Hummel and Johnson 1985). Similar results were obtained with container grown tree transplanted into a heavy clay soil (Corley 1984). It therefore appears that amending planting hole backfill has not been demonstrated to be either consistently beneficial or detrimental (Costello and Paul 1975).

CONCLUSION

It can be concluded that soil compaction pose and will continue to pose serious problem for the landscaping industry for as long as modern construction methods are used and people traffic continue to increase on landscapes. Soil with good structure need to be protected during construction and other compaction inducing activities. Efforts to improve plant establishment are often required, where damage has already been done. So far, no universally successful techniques is available. However, landscapers would have to understand how compaction affects the growth of trees and shrubs and the relationship between soil moisture, aeration and compaction. Although available amelioration methods have focused on soil aeration, it appears that as long as drainage is adequate aeration is most likely not the primary restricting factor resulting from soil compaction. Further studies should therefore focus on techniques that physically reduce mechanical impendence and improve soil tilth.

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