Causes of Soil Compaction

by Dr. Kim D. Coder, University of Georgia July 2000

In order to understand and visualize soil compaction more completely, the underlying causes must be appreciated. Soil compaction is primarily caused by construction and development activities, utility installation, infrastructure use and maintenance, and concentrated animal, pedestrian, and vehicle traffic. Below are listed individual components of how soil is compacted.

Conducive Moisture Contents – For every soil type and infrastructure situation there is a soil moisture content at which the soil can be severely compacted with minimal effort. These moisture content levels can be used to compact a soil for construction activities, but should be avoided when defending tree and soil health. Both direct impacts and vibrational energy will cause compaction when the soil is at or near its compaction moisture content maximum. Figure 1.

Pedestrian & Animals – The pounds per square inch of force exerted on the soil surface by walking, grazing, standing, and concentrated humans and other animals can be great. Problems are most prevalent on the edges of infrastructures such as fences, sidewalks, pavements, and buildings. Holding, marshaling, or concentration yards allow significant force to be delivered to soil surfaces. Paths and trails provide a guided journey of soil compaction.

Vehicles – Conveyances with tracks, wheels, and glides provide a great deal of force on the soil surface. Narrow rubber tires can transfer many pounds of compaction force to the soil. The classic example are in-line skates and high pressure bike tires. These wheels can impact soils beyond 60lbs per square inch. Broad, flat treads can dissipate compaction forces across more soil surface than tires, and reduce forces exerted per square inch.

Soil Handling – The movement, transport, handling, and stockpiling of soil destroys aeration pore spaces and disrupts soil aggregates. Soil cuts, fills, and leveling compacts the soil. Soil handling equipment can be large and heavy allowing compaction many inches deep.

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Vibrations & Explosions – Any mechanical energy that impacts individual soil particles can cause compaction. Car and truck traffic can cause vibrations which compact soils effectively at higher moisture contents. One solution to compaction in the past was use of explosives to fracture soils. The end result was the explosive energy fractured the soil in areas but heavily compacted the soil in other areas. Explosives damaged the soil to a degree not offset by aeration pores formed.

Intentional Manipulations – In order for infrastructures to be built and maintained, the supporting soil must be properly compacted. Because of how forces in soil are distributed beneath infrastructures, a compacted pad with slanted base sides must be build. This process assures that infrastructure edges, bases, and lifts (compacted fill layers) are heavily compacted. The only space available for tree root colonization are fracture lines and coarse building materials where large air spaces occur. The greater the compaction, the closer to the surface the soil anaerobic layer develops, decreasing effective rooting volume.

A note needs to be made here regarding pavements. Soil is a complex material with a unique thermal and moisture expansion and contraction pattern. Soil expands and contracts over a day, season, and year at different rates than adjacent pavement or hard infrastructures. As a result, fissures and fracture lines filled with air occupy the interface between soil and infrastructures. These aeration pore spaces can be effectively colonized by tree roots. If infrastructures are not ecologically-literate in their construction, tree roots can generate enough mechanical force to accentuate any faults present.

In addition to the aeration pore space from structure / soil interfaces, the coarse sub-grade and paving bed materials can provide moist aeration pore space for tree root colonization. The interface between pavement and its bedding material can be a well aerated and moist growing environment. Compaction may have caused anaerobic condition to be found close to the surface under pavement while the pavement bed may provide a secure colonization space for tree roots. Physical or chemical root barriers may be needed to prevent root colonization of infrastructure aeration spaces.

Water Interactions – Water influences soil conditions conducive for compaction as well as providing energy directly to the soil surface for compaction. Direct irrigation impacts from sprinklers or rainfall hitting the soil surface can cause crusting and compaction. Piling of snow in winter when the soil is frozen compacts little, but large snow drifts remaining on-site as soils begin to thaw can lead to compaction from direct contact as well as from maintaining high moisture concentrations allowing for long periods of compaction susceptibility.

Soil saturation allows for hydraulic pressure to destroy soil aggregates and move fine particles into aeration pore spaces. Flooding events can lead to dissolved aggregate coatings and aggregate stability loss. Erosional processes across the surface of the soil and particle movement within the top portions of the soil (dislocated fine particles) can lead to aeration pore space loss and crusting.

Organic Matter Loss – Organic matter is the fuel, short-term building blocks of soil structure, and supply warehouse for living things in the soil. As organic matter decomposes and mineralizes without adequate replacement, soil becomes more compacted. Bulk density increases and aggregate stability declines as organic matter is "burned " out of the soil.

Conclusions

Many activities of living in a modern society either require soil compaction or present soil compaction as a by-product. Many causes of soil compaction can be unexpected and hidden over time from the tree manager. Prevention of causal agents and processes is the first step in combatting soil compaction.

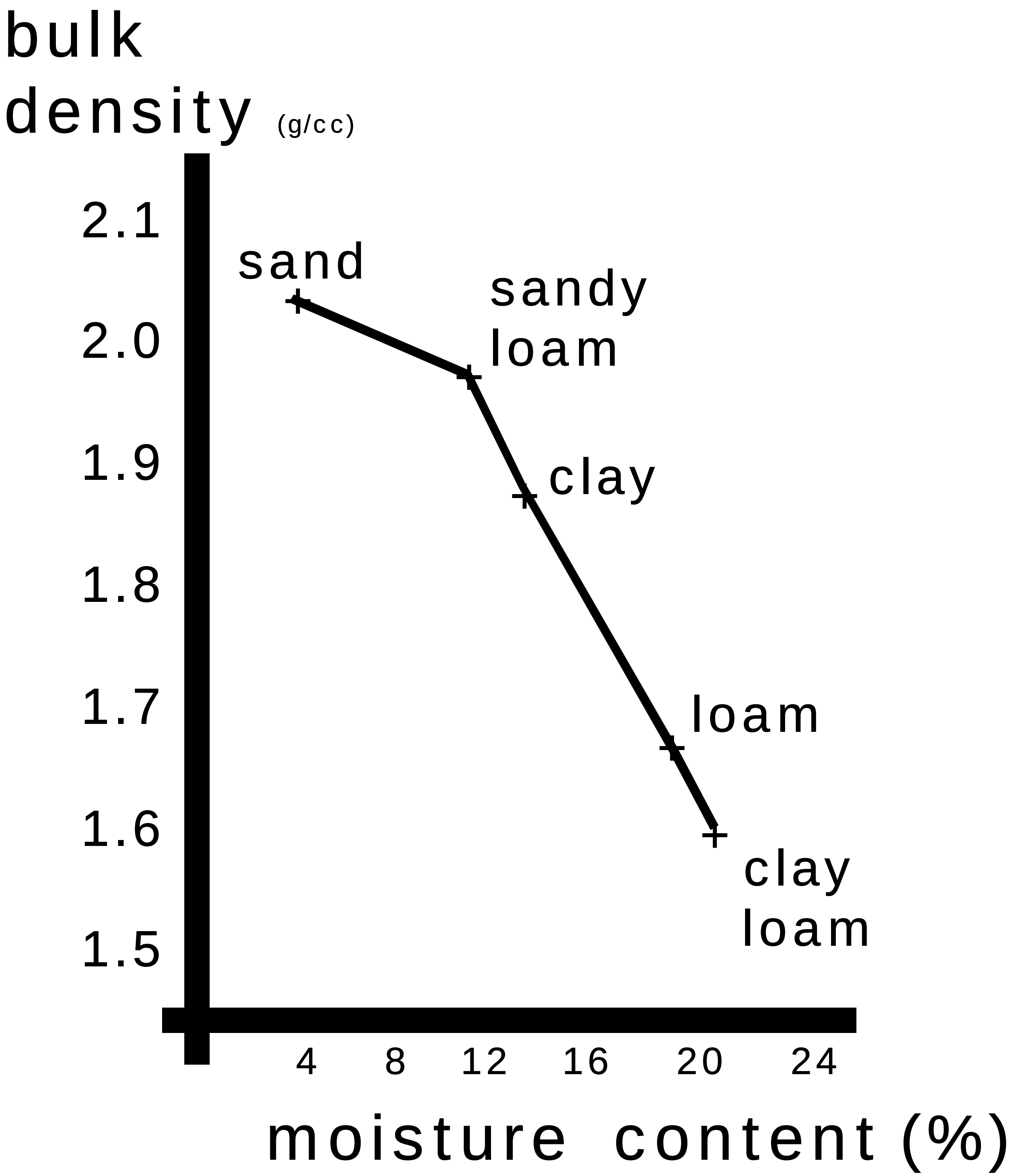

Figure 1: Maximum compaction capacity by moisture content.
(after Craul 1994)