THE SCIENCE OF SOILS FROM NEW TURF HANDBOOK

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Soils are composed of particles of an infinite variety of sizes and shapes. The soil profile, as described and classified by state and national surveys, is the result of gradual changes that have occurred during soil formation. More than 7,000 natural soil types have been identified and classified in the USA. Indiana has 36 groups of soils which include more than 700 types. A soil is typed according to its texture — sand, silt, clay. Soil types also reflect the parent material, drainage, climate, and vegetative growth associated with the soil during its formation.

Organic matter, the residue of plant decay, creates specific characteristics in the soil profile. The tall grasses of the prairies helped to create the deep black topsoils. The northern pine forests on the sandy soils in Michigan helped to create a leached organic upper and a dense lower soil horizon. Soils under hardwood forests are medium dark because they contain medium amounts of humus. Soils developed under low rainfall and high temperatures have little organic matter.

Dr. Daniel is in the final stages of writing his new "Handbook for Turf Managers." The book has 39 chapters on topics such as Management, Grasses, Rootzones, Pest Control, and Turf Uses. The new book will be available from Harvest Publishing Co. this spring.

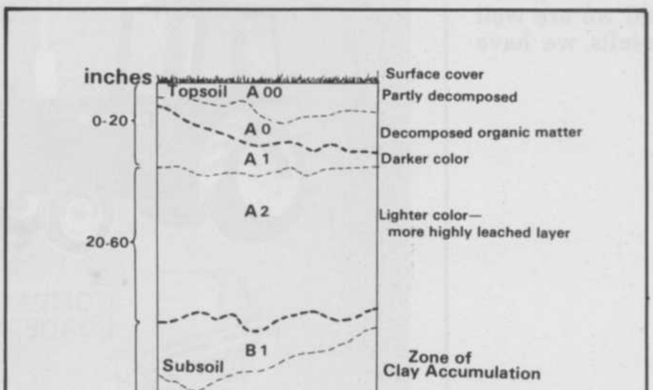

Figure 1: Drawing of a typical soil profile.

A. Source Of Parent Material

An infinite variety of physical and chemical forces have combined to create the different soils. Some of these forces are volcanic eruptions, freeze and thaw, mountain stream erosion and flash floods. Those big rough boulders of the mountain streams eventually become the gravel of the river, the sand of the shoreline, the silt and clay of the flood plain and the clay of the delta and the ocean floor. The process of erosion, grinding, wearing and sorting helps to produce many soil types.

Freezing and thawing as a weathering process is powerful. As water freezes it expands 9% or 1/11th of its volume. Every chip, crack or crevice becomes a pressure point. As the rock flakes, its surface is exposed to the weather's attack on its solidarity. Weathering is a process affecting all particles, tending to continuously subdivide them. This earth's covering is thin because weathering is primarily a surface phenomena.

The natural processes of soil formation are continuously at work. When soil particles are moved by water, gravel and sand particles settle quickly but move as the currents change. Clay settles slowly, and as a result, moves into deeper water where dense layers are formed. Periodically, a flood of incoming water contributes silt and sand to the clay layers. Eventually, the water level changes, the lakes dry up, the poorly drained flat plain is left with productive clay or clay loam soils.

In portions of Canada and central United States the glaciers of the ice age moved the material that other forces had assembled. Boulders were transported hundreds of miles, topsoil was stripped to bedrock (some areas in Canada), lakes were gorged (Finger Lakes of New York), old river valleys were buried (Teas River of Indiana), and new rivers formed (Ohio River). As the glaciers melted, their terminal moraines became gravel and sand deposits. Undulating as well as level land was left stony, or, in some cases, remarkably free of stones. Large gravel and sand deposits were created by the sweeping power of outwashes.

Winds play a continuing part in soil deposition or structure. The huge loess deposits downwind (east) of the Mississippi River, the sand ridges along creeks and lakes, and the sorting process across the deserts all illustrate the force of the wind.

Vegetation tends to stabilize soil surfaces as well as to produce organic matter for a multitude

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of organisms. As these organisms feed and die they effectively contribute to the granulating and structure creating processes of soils. The decay of plant parts accompanying the release and recycling of elements used in plant growth are fascinating conservation phenomena.

Chemicals and clays carried into the oceans gradually become sedimentary layers of limestone, sandstone, shale and other rocks. When lifted by geological forces, such as earthquakes, the new land exposed joins in this cycle of constant change.

Chemical processes, such as oxidation, solution, hydration, and carbonization, are constant acting factors making soil formation a continuous process. The result is the textured and structured soil that anchors the plant and serves as a reservoir of nutrients, water and air.

The different layers or *horizons* constitute the soil *profile*. The "A" layer of the profile is the zone of organic accumulation, the darker colored, structured topsoil. The second layer or "B" horizon, is made of clays and other fine particles collected as fragipans, or dense clay layers and subsoils. The "C" horizon is the parent material, which has been less affected by weather, water and organic matter interactions.

Many soils of western North America tend to be less developed since they have received limited water action in the recent geologic past.

B. Soil Texture

The sizes and shapes of soil particles determine the soil texture. The infinite variety of sizes are classified as colloids, clay, silt, sand, gravel and stone. Clay, silt and sand contribute most to soil-plant relationships.

B-1. Soil Texture Classification

Soil separate	Diameter	Particles/gm	Surface area in 1 g.
	mm	number	sq. cm.
stone	over 25	-	-
coarse gravel	25-5	1	-
fine gravel	5-2	30	-
very coarse sand	2-1	90	11
coarse sand	1.0-0.5	720	23
medium sand	0.5-0.25	5,700	45
fine sand	.25-.1	46,000	91
very fine sand	.10-.05	722,000	227
silt	.05-.002	5,776,000	454
clay	below .002	90,260,853,000	8,000,000

The intermix of particles has been classified into soil types based on the predominance of the fractions involved. (See Fig. 2). Sandy clay loam soil has only 20% clay but it is identified as such because clay particles characteristically standout. A soil must have more than 50% sand before it can exhibit the characteristics of a sandy soil. Silt particles act individually unless captured as organic aggregates or fragipans.

Cracking and fracturing of the soil is minimized when the clay content is less than 30% and is diluted with sand and silt.

C. Soil Structure

Soil structure is determined by the arrangement of soil particles within aggregates, granules and clods. Cations, colloids and humus contribute to their formation and stability.

Most clays have a net negative charge which allows the particles to join with positively charged ions such as calcium (+2). Bacteria and fungi produce secretions and decaying plants release compounds which cement particles together.

D. Topsoil

A medium sandy loam topsoil containing sufficient organic matter (5-10% by volume or 2-3% by dry weight) should be well granulated. The degree of granulation is expressed as the percent of the silt and clay content occurring as aggregates. A soil with 60% aggregates is considered to have good structure.

Aggregates of soils created by binding agents, colloids, cations, humic acids, and decaying organic matter are more stable to the forces of water. In comparison, aggregates formed by physical forces such as wetting and drying, freezing and thawing, and /or tillage operations are relative unstable.

In general, topsoils which drain well enough to allow air into at least 25% of the pore space (or 10% of volume) within twelve hours of saturation are considered satisfactory for most uses.

E. Topsoil Standard

The British (B.S. 3882:1965 of British Standards Institution) have identified topsoil into categories:

Topsoil is the existing surface layer of grassland or cultivated land. It is usually a darker shade of brown to black because of its organic matter content mixed with the mineral matter. Topsoil tends to be friable and show some degree of poros-

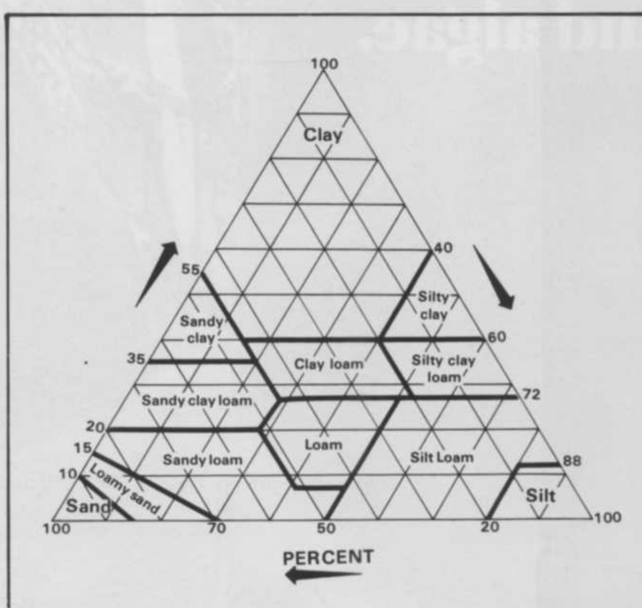

Figure 2: Textural triangle showing the various soil types.

ity. Topsoil texture may be classified as:

Light topsoil contains a high proportion of sand. It may be possible to mold it when moist, but it will lack cohesion and fall apart easily.

Medium topsoil contains a blend of soil textures. It can be easily molded when moist but it is not sticky and does not leave a smooth polished surface when smeared.

Heavy topsoil contains a high proportion of clay. It is sticky when moist, slippery when wet, and leaves a smoothed polished surface when smeared.

Topsoil may also be classified by pH and stone content.

Soil for ordinary use may include a few stones up to 5 cm or two inches in diameter. For turfgrass areas, the larger stones need to be removed. For athletic fields, playgrounds, or where body contact is made with the soil, stone-free soil is recommended.

E-1. Topsoil classified based on its pH.

Description	pH
alkaline	more than 7.5
slightly alkaline	7.0-7.5
slightly acid	6.0-7.0
acid	less than 6.0
strongly acid	less than 5.0

Stone is defined as any inorganic particle larger than 25 mm (1 inch). The size of gravel is 2-25 mm.

E-2. Topsoil classified as to content of stone

Class	% by weight
stone & gravel free	less than 1%
slightly stony	1-5
stony	5-20
very stony	20-50
extremely stony	over 50

F. Bulk Density

Well aggregated soils, when oven-dry, may have a bulk density of 75 to 95 pounds per cubic foot. These soils at field moisture capacity would be 90-115 pounds per cubic foot.

Loamy sand has a bulk density of 82-102 pounds

F-1. Bulk Density, Porosity, and Hydraulic Conductivity of a Loamy Sand Under Various Levels of Compaction.

Compaction Intensity	Bulk Density cu. ft. lbs.	Bulk Density cc gm	Aeration Porosity %	Hydraulic Conductivity inches/hr.
Lowest	82	1.31	21.5	6.5
		1.45	20.8	1.4
		1.49	10.0	0.9
		1.60	11.0	0.2
Highest	1.02	1.64	10.9	0.2

per cubic foot, depending on the degree of compaction imposed.

Stones or solid portions of soil have a density of 166-172 lbs./ft.[3], depending on the mineral composition. The density of quartz, feldspar and sandstone is 166 lbs./ft.[3] Heavy metallic ores may have a density of 370 lbs./ft.[3] Water has a density of 62.4 lbs./ft.[3]

The results shown in Table F-1 indicate that as compaction increased, bulk density increased while porosity and hydraulic conductivity decreased markedly. The moderate and high compaction intensity characteristics are certainly realistic under heavily used turfed areas. Therefore, it is not surprising to observe a decrease in both infiltration and percolation rates on golf courses, athletic fields, etc., with time. The decrease in infiltration rates under use conditions should be anticipated during design of the rootzone. The rates are not necessarily the same as that of the initial rates observed under a non-compacted situation.

F-2. Approximate Topdressing Quantities per 1,000 sq. ft.

⅛"topdressing requires 0.4 cu. yds.
¼" topdressing requires 0.8 cu. yds.
1" soil layer requires 3.1 cu. yds.
12" soil layer requires 36.7 cu. yds.

F-3. Weight of Soils and Materials

Material	Condition	Weight per cu. yd.	Weight per sq. meter
		lbs.*	kg
loam	loose	2200	1320
loam	compact	2550	1530
clay	compact	2700	1620
clay	wet	3050	1830
clay sand	compact	3250	1950
silty sand	wet	3100	1860
sand	dry	2700	1620
gravel		3450	2070
crushed stone		3600	2160
peatmoss	compact	450	270
peatmoss	loose	110	66
water		1690	1000

*Factor used is 0.6

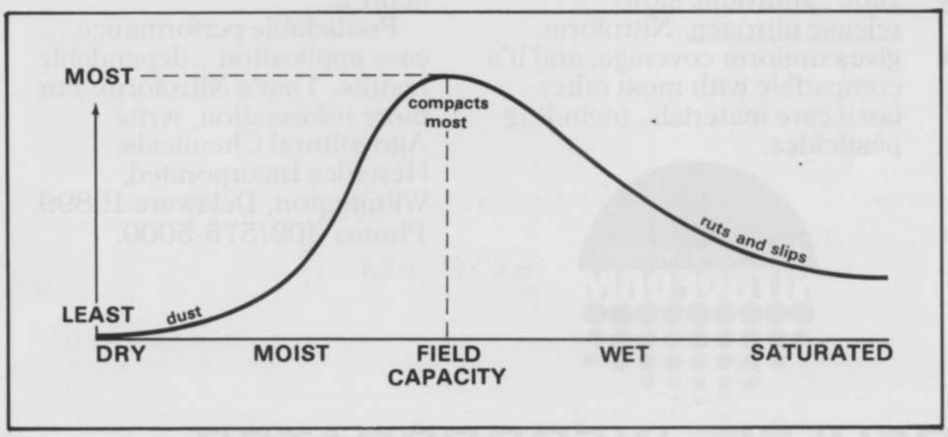

Figure 4: Most compaction occurs when the soil is at field capacity of water.

H. Compaction

Soil compaction results when the soil particles of clay and silt are crushed together. Pore space between the closely packed (kneaded) fine particles inhibit both the escape of air from the soil and the infiltration of water. During dry periods surface hardness, cracking, and dust accumulations are evident in compacted soils.

Soil compaction caused by foot and vehicular

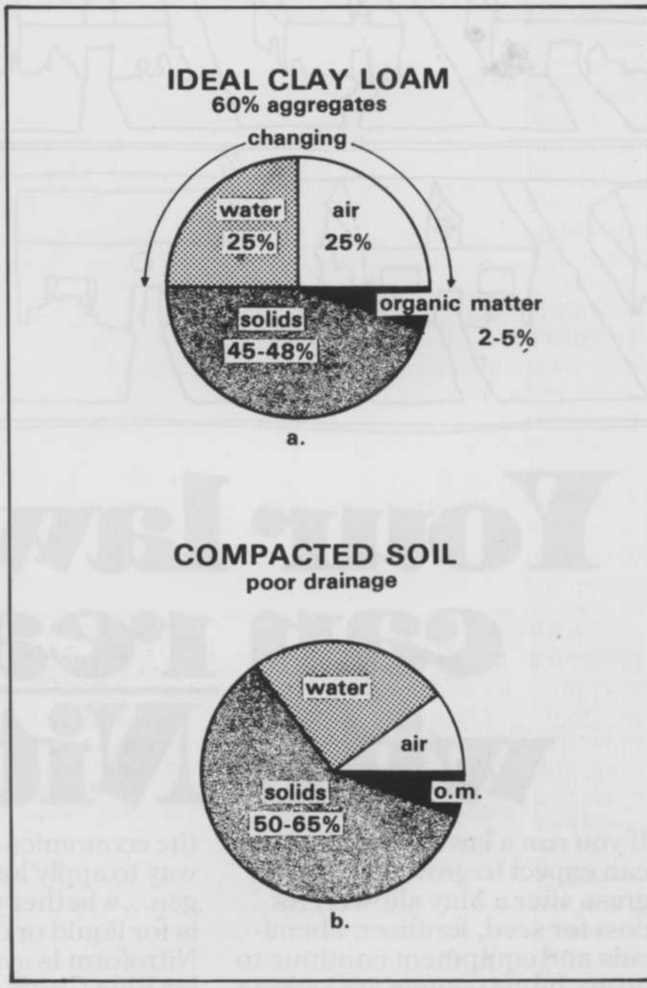

Figure 3: Circle graphs showing reduction in soil gases in compacted soil.

traffic is a common problem of turfgrass areas. As compaction develops, turfgrass loses vigor and density, and root growth becomes restricted because of the low oxygen supply. Table Fig. H-2 illustrates the effect of compaction in reducing non-capillary porosity in a specific soil test. The

H-2. Effect of Foot Traffic on Top Inch of Soil

Compaction	Infiltration per hour	Run-off of rain water	Non-capillary Porosity-volume
	inches	%	%
none	1.5	0	33
moderate	.7	52	19
heavy	.3	76	6

rate of oxygen diffusion is drastically reduced when only 6% non-capillary pores are present, for these may be isolated rather than continuous.

In a nine year study of compaction the air porosity decreased from 21 to 17%, while infiltration was reduced from 45 to 32 cm/hour. Heavy compaction caused a 22% lower air porosity and a 46% lower infiltration rate when compared to normal maintenance for a putting green in Virginia, 1966-74.

The finer soil particles exert more influence on soil characteristics due to their greater surface area compared to larger particles. (Fig. 4) Particles two grades smaller in textural size will pack the available space within the larger fraction. Thus 70% coarse sand combined with 30% fine sand has the drainage characteristics of fine sand.

A compacted mixture composed of 25% (weight) particles of silt and clay can effectively fill all large pores. Because of the large number of particles, the finest 10% of the soil dominates over the 90%. The 90% will have variation, which lends some effects in distribution, but the finer particles, whether mixed by nature, by cultivation or com-

H-4. Correlation of Putting Green Condition With Oxygen Diffusion Rates at Different Soil Depths

Depth	Oxygen Diffusion Rate*		
inches	good	declining	bad
2	52	15	10
4	27	15	10
12	4	4	?

*Measured in grams per square centimeter per minute (average for 20 measurements). An oxygen diffusion rate value of 20 is considered the critical level. Values below this figure will not support satisfactory growth of grass roots.

paction, will control the pore sizes or openings and thus the movement of water and air. The coarsest particles, being large and solid, actually add more interference than if only small particles were present.

The composition of some soils can be compared to that of concrete where gravel particles, sand, cement and water are combined so that each particle settles against and between others. The density of concrete is approximately 2.4, while the density of compacted soil mixtures ranges from 1.3 to 1.7. (See F-1).

I. Pore Space

One of the long standing practices of turf care has been the use of topdressing. Equal portions of sand, soil and peat have traditionally been used. More recently, turf managers have been increasing the proportion of sand in the mixes for topdressing.

The impact of traffic and compaction on pore space in soils should not be underestimated. The initial appearance of a topdressing mixture is altered by compaction as its structure is destroyed and only the texture contributes to pore space. The combination of topdressing components which provides the least pore space after compaction is called the "threshold proportion."

Spomer of Illinois reports 37% pore space of a compacted (single sized) monotextured particle rootzone. A graded mixture of sizes usually contains less than 27% pore space. The "threshold" value of mixes tested was 18% pore space. The mix was comprised of 100 parts sand and 36 parts "soil" mixed and compacted. Each sand and soil varies in proportions required to achieve threshold values.

An interesting fact is the pore space remaining when the sand particles are pushed together by compaction. Uniform size spheres (i.e. marbles) will have 44% pore space. Naturally occuring sand includes a variety of particle sizes. A sample of medium sand had 37% pore space. A mixture of all sizes of sand (good for making mortar) has approximately a 27% pore space. Sand diluted with silt and clay can have as little pore space as 18%. Understanding these relationships increases the appreciation of the variation found in sand and soil rootzones for turfgrass production.

The natural process of wetting and drying, freezing and thawing, granulation and compaction, root production and decay, percolation and leaching, interact with the soil mass as a continuing part of the dynamic soil process. Management programs may include mechanical cultivation to counteract compaction, sand additives to improve infiltration and earthworm activity to dilute thatch. In principle, water and air should freely go into and out of a rootzone. **WTT**

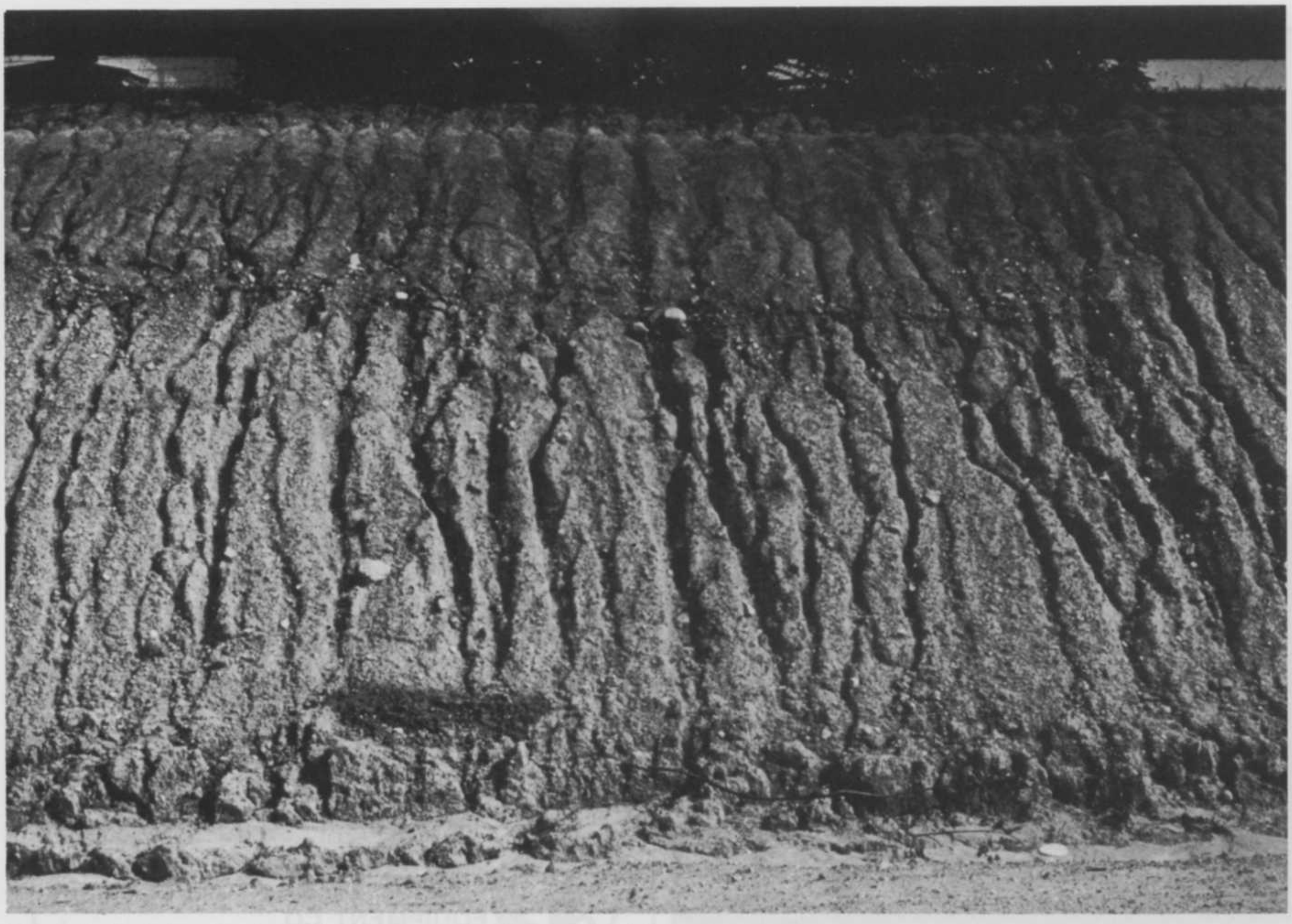

Figure 5: Eroded road cut could have been avoided by proper sodding and soil preparation.