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Cover Photo:

The Mall, looking East, viewed from the Washington Monument. Photo by Bill Clark, NPS National Capital Region.

Urban Soils of the Mall in Washington, D.C.

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Urban, or highly man-influenced, soils are becoming more commonplace with the extensive earth moving and manipulating activities of man. Such soils are not limited to urban areas, but may be found wherever activities of man result in disturbance of soil profiles. Disturbance may consist of compaction of an existing soil by foot traffic, or may result from large scale manipulation of soil materials to create entirely new land surfaces.

Urban soils have unique properties resulting from their mode of formation and the impact they receive. It is important to understand the properties of urban soils in order to manage them effectively as a resource, whether the soils are situated in an urban or rural setting. The study of urban soils is a new facet of soil science, with much to be learned. Since the National Capital Region is largely an urban park system, regional scientists have initiated a program to characterize urban soils.

Urban Soils and NCR

Parklands of the National Capital Region (NCR) receive heavy visitor impact, with many soils occurring on highly manipulated landforms. This impact, plus the need to maintain high quality, attractive plantings, provided the incentive to study the Mall soils intensively.

The Mall is managed by the National Park Service and is situated between the U.S. Capitol to the East and the Washington Monument to the West (cover photo). The soils of the Mall may be typical of highly man-influenced soils because they have evolved from fill material and are continually impacted by pedestrian and vehicular traffic. The Mall is often the site of major events such as the Festival of American Folklife.

The objectives in studying these soils were to: 1. determine their physical and chemical properties; 2. determine the variation of these properties; 3. develop a soil map based upon observable soil

properties; 4. attempt to classify them in a manner indicative of their highly man-influenced nature; and 5. provide management information to the Park.

A soil's physical properties are among the most difficult to modify, and yet can exert a profound influence on its management. Properties such as texture, bulk density, and amount of pore space determine the air and water relations within the soil profile. The mode of formation of these soils can result in strongly contrasting soil layers or horizons.

The soils of the Mall have developed in miscellaneous fill applied to a depth of about 6 m (20 ft.). Sharp delineations between contrasting soil materials (lithologic discontinuities) were found in 95 percent of the profiles. A lithologic discontinuity is the point in the soil profile where a change in particle size and/or mineralogy occurred prior to soil formation. A lithologic discontinuity is, therefore, the distinct boundary between two contrasting soil materials. These lithologic discontinuities can result in poorly drained soils, which often can be identified by mottled colors within the soil matrix. Artifacts of man, such as brick, glass, cinders, concrete, and slag, were found between 25 cm and 100 cm in 94 percent of the profiles.

The presence of artifacts within the soil profile was significant as they demonstrated that man was instrumental in the accumulation of the parent material.

Further evidence of manipulation of the soil materials was indicated by the presence of buried A horizons and the variation of percent organic matter with depth in the profiles (Table 1). Soil A horizons are generally considered to be surface horizons, and are characterized by accumulations of organic matter. These horizons are usually darker in color than underlying horizons, with a softer, more friable, consistence. When fill material was deposited on the existing native soil surface, any A horizon which may have been present at the time of filling would have been buried. That soil formation occurred in this fashion on the Mall is evident by the presence of buried A horizons in 42 percent of the profiles studied.

The soils were found to be predominately loamy, which connotes a relatively balanced distribution of sand, silt, and clay particles. Such a texture provides a reasonable compromise between the drainage afforded by sand, and the water-holding capacity afforded by clay. However, loamy soils tend to be susceptible to compaction because the relatively even distribution of particle sizes permits small particles to be readily compressed into voids between larger particles.

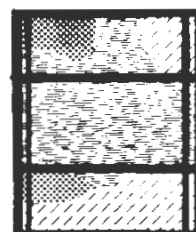
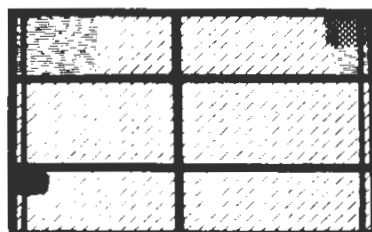
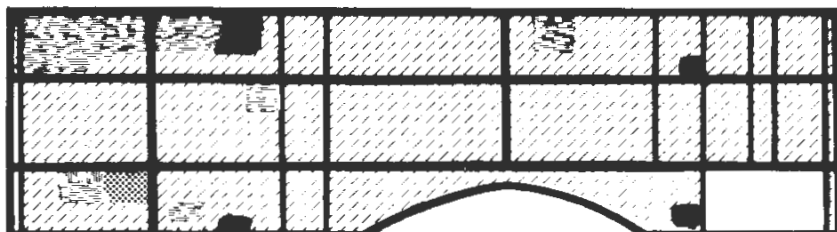
Table 1.
Mean of Selected Chemical Properties
of Mall Soils by Horizon.

Horizon (from surface)	pH	Organic Matter %
1	6.39	1.97
2	6.52	1.08
3	6.57	0.73
4	6.64	0.50
5	6.67	0.41
6	6.59	0.66

The visitor impact the Mall receives has resulted in an increase in bulk density, which is the weight of soil material in a given volume. The bulk density of an ideal soil is approximately 1.33 grams cubic centimeter (g cc). The soils of the Mall had a mean bulk density of 1.61 g cc in the surface horizon, and 1.74 g cc at 30 cm (Table 2). Bulk densities up to 2.03 g cc were observed. Studies have shown that soils with bulk densities of 1.67 g cc or greater are often inhospitable to plants. The main result of compaction is a loss of pore space. While an ideal soil will contain approximately 50 percent total pore space, evenly distributed between air and water, the mean percent pore space of Mall soils was only 36.6 percent at the surface, and was 32.8 percent at 30 cm. These soils often have less available moisture as a result of the reduced pore space. The lack of sufficient pore space



-  Urban Udorthent (artifacts; little soil development)
-  Urban Eutrochrept (artifacts; more developed soils; more nutrients)
-  Spolic Eutrochrept (no artifacts; more developed soils; more nutrients)
-  Urban Dystrochrept (artifacts; more developed soils; fewer nutrients)
-  Spolic Udorthent (no artifacts; little soil development)



Detailed soil map of the Mall.

usually causes stress to plants. The packing of soil particles restricts root penetration, contributing to plant stress. A root system limited in extent by com-

are important to soil management. Some of these properties, such as pH, are more easily manipulated than the physical characteristics, although other properties, such as heavy metal content, cannot be easily modified. Knowledge of these characteristics is essential for satisfactory management.

Hydrogen ion concentration (pH) of a soil affects the retention and availability of nutrients by soil constituents. The mean pH of Mall soils ranged from 6.39 in the surface horizon to 6.67 in the 5th horizon (Table 1). However, pH values for 32 percent of the samples obtained were 7.0 or greater. These alkaline pH values may be a result of inclusion of lime-releasing artifacts, such as concrete, mortar, or compost, within the profile. Analyses have indicated that calcium was the dominant cation held within the exchange complex of the soil, possibly as a result of inclusion of lime-releasing artifacts within the profile. Lime should not be applied routinely to highly man-influenced soils such as these without testing. The value of a soil testing program is not limited to urban soils, but is applicable to any managed soil. Soil testing should not be restricted to pH determinations, but should be performed to determine fertilizer requirements as well.

Organic matter in soils is highly beneficial. A favorable environment for soil fauna and mycorrhizal fungi

is provided by organic matter. As organic matter decays, it releases nutrients, acting as a slow release fertilizer. Organic matter also tends to improve the soil structure by acting as the "glue" binding the individual soil particles into larger aggregates, or peds. These aggregates improve drainage, aeration, and water infiltration capabilities of fine-textured soils, and increase resistance to compaction for most soils. Organic matter also increases the ability of the soil to retain nutrients, preventing them from leaching from the soil. The organic matter content of urban soils tends to vary with depth, and is often lower than that of natural soils because organic matter may be removed during routine maintenance practices such as mowing, dethatching, and leaf collecting.

The mean organic matter content of Mall soils tended to be low, less than 2 percent in the surface horizon, and decreased with depth (Table 1). Most natural soils in the Washington, D.C. area contain from 2 percent to 4 percent organic matter in the surface horizon. The low organic matter content, in conjunction with the loamy textures, caused these soils to be susceptible to compaction. Much of the buffering capability of organic matter to changes in pH and nutrient status is lost because of the low level of organic matter present in the soils.

pacted soil will create root-crown imbalance and result in a stressed plant, which will be most evident in dry periods. Storage of energy reserves in the root system also is reduced. Methods to alleviate or prevent soil compaction are, therefore, necessary.

The chemical characteristics, such as pH, organic matter, soluble salts, and heavy metals, also

Table 1. Vegetation Information Baseline Summary

Park	Approximate area (acres)	Vascular plant checklist or collection	Non-vascular plant checklist or collection	Endangered plant list	Exotic plant list	Vegetation map	Vegetation plot system
Isle Royale NP	571,796	yes	inc.	yes	yes	yes	yes
Voyageurs NP	219,128	inc.	inc.	inc.	—	yes	yes
Ozark NSR	81,216	yes	inc.	inc.	—	yes	—
St. Croix NSR	73,578	—	—	inc.	inc.	yes	—
Pictured Rocks NL	72,259	yes	—	inc.	yes	yes	—
Sleeping Bear Dunes NL	71,105	inc.	—	—	—	—	—
Apostle Islands NL	42,009	yes	inc.	yes	—	yes	—
Cuyahoga Valley NRA	32,460	inc.	—	inc.	—	inc.	—
Indiana Dunes NL	12,535	yes	—	yes	yes	inc.	—
Agate Fossil Beds NM	3,055	inc.	—	—	—	—	—
Scotts Bluff NM	2,997	inc.	—	—	—	—	—
Wilson's Creek NB	1,750	yes	—	inc.	—	inc.	—
Effigy Mounds NM	1,474	yes	—	—	—	—	—
Fort Larned	718	yes	—	inc.	—	yes	—
Grand Portage NM	710	—	—	—	—	yes	—
Pipestone NM	282	yes	—	—	—	—	—
George Washington Carver NM	210	yes	inc.	—	—	yes	yes
Lincoln Boyhood NMem	196	—	—	—	—	—	—
Homestead NM of America	195	—	—	—	—	—	—
Herbert Hoover NHS	187	—	—	—	—	—	—
Mound City Group NM	68	inc.	—	—	—	—	—
Fort Scott NHS	17	—	—	—	—	—	—

Studies (2,3,6,7,11) have shown that soils in urban areas often have elevated levels of soluble salts and heavy metals. The soluble salt content of the Mall soils was found to be low, with most soils containing less than 300 ppm. Cadmium, nickel, zinc, and copper levels were similar to background levels reported in the literature, but the lead content was slightly elevated.

The Mall soils varied greatly in the number of samples required to estimate the mean for the properties examined. The physical properties tended to require fewer samples than the chemical properties to estimate the mean at a given level of accuracy. Determination of mean bulk density could be accomplished with only one sample, while up to 7,171 samples would be required to estimate the mean nickel content! Other properties were intermediate in their variability. Therefore, it is apparent that soils which have developed in manipulated soil material will require a greater amount of sampling than soils in nonimpacted areas.

A soil map of the Mall was prepared using taxonomic criteria developed for use with highly man-influenced soils. Subgroups previously developed for use with highly man-influenced soils, with "urbic" and "spolic" subgroups, were used in conjunction with standard soil taxonomy. The urbic subgroup consists of those soils which have been manipulated and contain artifacts of man, while the spolic subgroup consists of manipulated soils with no artifacts. The results of this reclassification were used to develop the soil map shown here.

Conclusions

The NCR is following a soil management program that includes aeration of these dense, compacted soils and topdressing with organic matter such as composted sewage sludge. Using post-and-chain to restrict visitor access in the most heavily impacted areas has aided recovery of some elm trees in highly impacted soils. Addition of woodchips in very heavily impacted areas where turf cannot tolerate the extreme wear has proven successful in minimizing soil compaction.

Management of highly man-influenced soils is made more complicated by their variable characteristics. Their compacted nature, with the resulting reduction in pore space, makes plant management difficult. Their texture makes them susceptible to compaction and, therefore, less able to support activities without being adversely affected. Layering of the soils during filling creates lithologic discontinuities that generally result in soils with poor drainage, moisture-holding capacity, and aeration. The chemical properties of the Mall soils are influenced by their highly impacted nature. Lead content, though elevated, is not limiting to plant growth. The great variation in some of the properties required over 7,000 samples in order to estimate the mean. Clearly, it is impractical to routinely perform sampling of this magnitude! However, no mat-

ter where such soils are found, the great variability of highly man-influenced soils will require more intensive sampling than natural soils to gain the same information for effective management. This study provides an example of how gathering basic data on a Park resource can provide management with information needed to effectively manage a challenging resource problem. For example, this study has shown that soil compaction is a serious management problem, and maintenance practices to minimize compaction should be implemented. Although the results of this study were obtained from a park in an urban area, the principles obtained are applicable to any park situation where impacted soil systems are located.

Short is a Soil Scientist and Patterson is Research Agronomist at the Ecological Services Lab, National Capital Region.

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