CHARACTERIZATION OF STREETSIDE SOILS
IN SYRACUSE, NEW YORK[1/][2/]

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ABSTRACT.--Streetside soils are shown to have bulk density, pH, specific conductance, and weight loss on ignition somewhat higher than native soils, and lower air-filled pore space and available water. Aeration status of the soil is shown to be a potential major problem, whereas street salting has a small effect on calculated osmotic potential.

THE PROBLEM

In 1961, John Van Camp (1961) gave a paper at the 37th National Shade Tree Conference professing the importance of a healthy root system to the vigor of a tree, and discussed the relationship between a tree and the root environment. He concludes his paper with "much basic research work and many intelligent observations are needed if we are going to keep pace with the tree problems that lie ahead." The problems that lie ahead are here and yet we have accomplished little basic research on the soil environment.

One omission is basic data on streetside soil physical and chemical properties. Since these soils are disturbed or manipulated, they do not always have the expected properties of native or natural, undisturbed soils. A confounding factor is the complex root environment found below

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[1/] Funded through cooperative aid grant 23-002 from U.S. Forest Service, Urban Forestry Project, Syracuse, N.Y.

[2/] Metro. Tree Impr. Alliance (METRIA) Proc. 3:88-101, 1980.

a planted tree (Figure 1). Three soil materials are present through which the tree roots must elongate: (1) the tree ball; (2) the backfill soil; (3) the soil material in which the tree pit has been prepared. Tree roots should penetrate the surrounding soil material (3) in two to three growing seasons (Lyford and Wilson, 1966). It is this material which interests us as soil scientists concerned with the longevity of the urban tree rather than planting survival. The latter is a separate question and is left to another study.

TPE STUDY

To develop basic information on streetside soil physical and chemical properties, 128 tree planting sites within the city of Syracuse, N.Y. were observed for profile characteristics, and soil samples obtained for laboratory analysis of bulk density, pH, weight loss on ignition, specific conductance, chloride content and available water (Black, 1965). These sites were sampled through a tree replanting program of the Syracuse Department of Parks and Recreation, and therefore were non-uniformily distributed over the five geomorphic surfaces comprising the city landscape: upland till plains thick to bedrock, upland till plains thin to underlying bedrock, alluvium and gravel floodplains, glacial outwash, and urban made land (Figure 2). The soils are comprised of shallow to deep calcereous glacial till soils in various drainage sequences, with and without a fragipan, moderately deep alluvium and deep gravelly well-drained outwash soils, and urban made land, consisting of hard and soft fill,over somewhat poorly drained to poorly drained soils, created as the city developed from its first settlement. The modifications of the soils are related to the landform and the chronological age of the development. Physiographic modifications were made only where necessary in the early urbanization of the city. The flat valley areas (alluvium and glacial outwash) required little modification. Hillslopes required more cut and fill and are more highly modified, but the basic topographic shape was maintained. More recent urbanization into these areas result in greater modification of the surface and hence, the soil profile due to the availability of heavier machinery. Fill is highly modified regardless of where it occurs. The less densely urbanized suburbs exhibit topographic features and soil profiles nearly similar to those of the natural landscape.

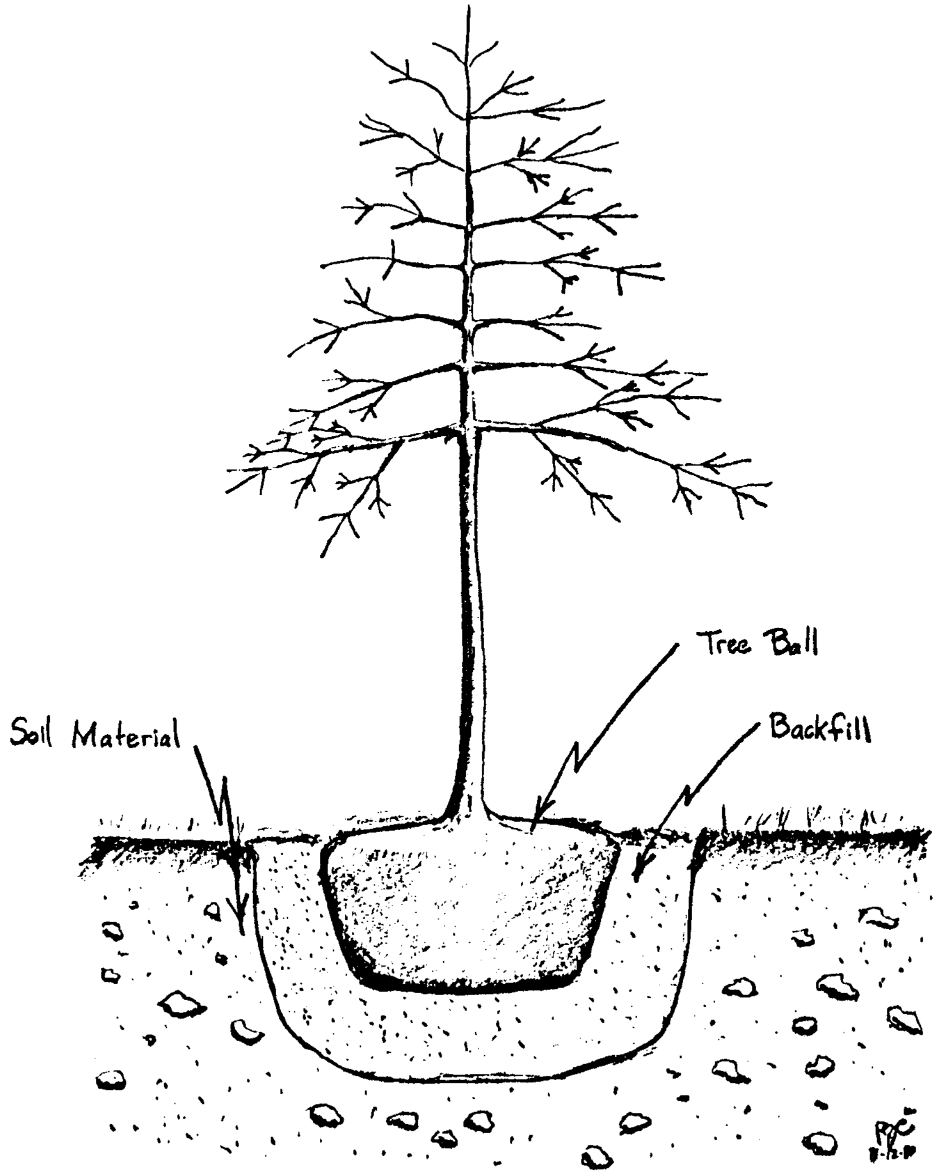

Figure 1. The planted tree showing the ball, backfill, and surrounding soil material.

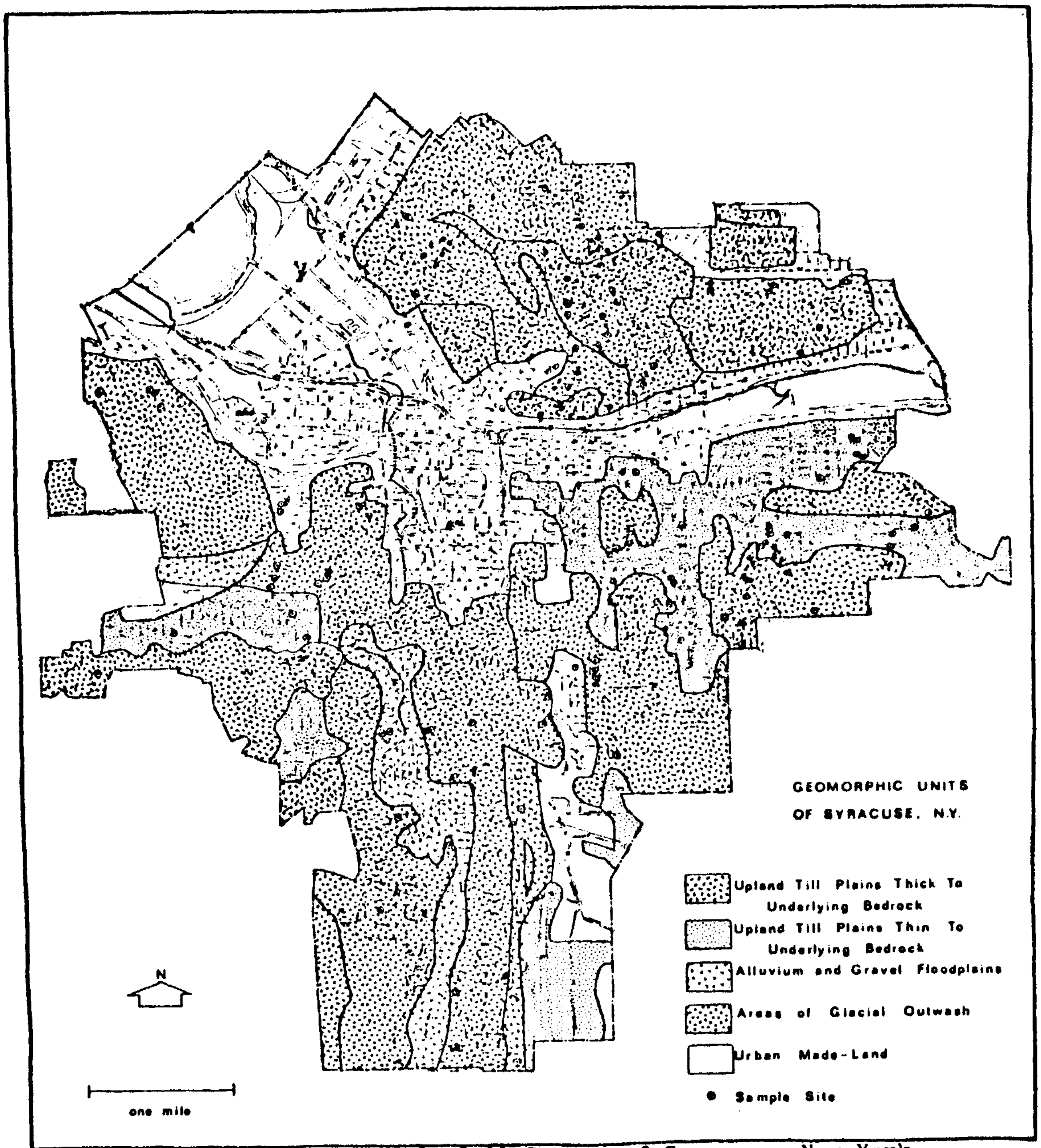

Figure 2. Geomorphic Soil Groups of Syracuse, New York
(from Soil Association Map, aerial photographs in
Onondaga County Soil Survey Report)

STREETSIDE SOIL PROPERTIES

Profile Modification

Profile modification is defined as that condition in the soil profile where: (1) some portion of the upper profile consists of material placed as fill over a natural soil or a portion thereof hence a lithologic discontinuity; or (2) the upper portion is stripped away and later replaced with the same material; or (3) the entire soil profile may consist of fill. The modification may be comprised of changes in properties such as bulk density, structure, possibly texture and organic matter, as well as the chemical properties of pH and nutrients. These changes are partially caused by intermixing or incorporation of non-soil material commonly associated with development construction such as fragments of brick, coal, wood, metal, ashes, etc. The extent and degree of modification has varying levels of influence on tree root growth as correlated with its effect on the ease of root penetration, available water, air-filled pore space and possibly, nutrient status.

The observed streetside soil profiles of Syracuse appear to fall into five modified profile classes: (1) 6 cm to natural profile or least modified of the sampled soils, and include mostly the glacial outwash and alluvial soils; (2) 11 cm to natural profile of glacial outwash soils; (3) 35 cm to natural profile mainly on thin glacial till soils; (4) 55 cm to natural profile on thick and thin glacial till soils and upland outwash; (5) 65 cm or more in fill to a natural profile or watertable comprising most of the urban made land of Figure 2. However, several of these classes may be represented within a landscape, and the average profile values for layer depths have the effect of masking any clear relationships between depth of modification and average values of soil physical properties different from what would be expected in the natural profile. The evidence for modification was primarily on the basis of the presence of incorporated non-soil material in the profile, some changes in color and the appearance of a structural discontinuity between layers. Additional analysis of individual profile data is required to develop a clearer relationship between modification and significant differences in bulk density, available water and air-filled pore space.

Soil pH

Relatively high pH values (Table 1) are expected since most of the soil parent material in the Syracuse area is influenced by outcropping and intermixing of material from various limestone strata. Comparison with the pH values of natural soils in Table 2 indicate that the pH values for the streetside soils are at the upper limit of the ranges for natural soils. The values are further inflated due to the use of calcium chloride as salting material on streets in the winter, and subsequent leaching has moved the calcium into the subsoil. Free carbonates have been observed in several of the profiles.

Specific Conductance

The specific conductance values are quite variable between soil groups as well as within'the profiles. The large values observed in the recent alluvium soils (Group IV, Table 1) may be due to accumulation through concentration of drainage water in this portion of the landscape. Values over 1.0 mmho/cm are necessary before most plants are affected (Wilde et al., 1972). Further, calculations using the formula:

osmotic pressure, bars = 0.36 x EC, mmho/cm

yields values that range from .22 to .94 bars with no established pattern among soils or within profiles. The contribution of osmotic potential to the soil solution was not sufficient to have a significant effect on increasing the moisture content of wilting point. Examination of the soil moisture in Table 3 leads us to believe that the osmotic potential would need to be several bars before significant effects are observed in these soils, since there are other more significant problems for root growth. However, specific conductance should not be ignored where soluble salts may be a contributory cause to adverse root environment.

Loss on Ignition

Weight loss on ignition of the profiles in Table 1 show the usual surface to subsoil trends found in natural soils. The values themselves are somewhat suspect in that the ignition procedure volatilizes carbonates as carbon dioxide when present in high amounts. This is probably the case in these soils, as subsequent chemical analysis shows high calcium

Table 1. Average soil property values for Syracuse streetside soil groups.

Soil Group	Number of Profiles	Layer Depth cm	Soil Reaction pH and Range	Specific Conductance mmho ± S	Loss On Ignition % ± S	Bulk Density g/cc ± S
I Glacial Till Uplands	53	0-16	7.7 (6.6-8.6)	.95 ± .26	7.2 ± 2.07	1.56 ± .07
		16-54	8.0 (7.1-9.1)	.62 ± .22	3.2 ± 1.10	1.82 ± .09
		54-65+	7.9 (7.3-8.8)	.61 ± .19	2.4 ± 1.15	1.85 ± .17
II Glacial Till Uplands Thin to Bedrock	18	0-10	7.9 (7.6-8.5)	.82 ± .29	7.1 ± 1.17	1.59 ± .07
		10-35	8.2 (7.4-8.6)	.57 ± .23	3.0 ± 0.63	1.84 ± .09
		35-65+	8.1 (7.5-8.6)	.64 ± .27	2.7 ± 0.53	1.81 ± .06
III Glacial Outwash	34	0-12	7.8 (7.1-9.0)	.78 ± .33	6.6 ± 1.38	1.62 ± .08
		12-38	8.0 (7.3-8.8)	.58 ± .14	3.3 ± 0.83	1.83 ± .17
		38-65+	8.0 (7.3-8.7)	.62 ± .52	3.0 ± 0.90	1.90 ± .06
IV Recent Alluvium	2	0-12	7.8 (7.3-8.6)	1.82 ± .28	6.3 ± 0.03	1.54 ± .01
		12-38	7.9 (7.6-8.2)	1.19 ± .18	4.0 ± 0.32	1.71 ± .03
		38-65+	8.2 (8.1-8.2)	2.60 ± .14	3.3 ± 1.35	1.60 ± .01
V Made Land	21	0-10	7.7 (7.3-8.5)	.89 ± .69	6.7 ± 1.65	1.73 ± .09
		10-35	8.0 (5.7-8.9)	1.45 ± .48	4.2 ± 1.30	1.82 ± .14
		35-65+	8.1 (7.7-8.6)	.66 ± .31	3.0 ± 1.57	1.79 ± .15

Table 2. Average soil characteristics for selected natural soils of Central New York.[a]

Soil Group	Depth cm	Soil Reaction Range, pH	Bulk Density and Range, g/cc	Available Water and Range cm^3/cm^3
I	0-30	5.6-7.3	1.39 (1.27-1.51)	.18 (.13-.20)
	30-83	5.6-7.8	1.59 (1.39-1.70)	.14 (.11-.18)
	83-152+	7.4-8.4	1.89 (1.73-2.00)	.08 (.06-.10)
II	0-41	5.6-7.3	1.14 (---)[b]	.15 (.14-.16)
	41-56	5.6-7.3	1.25 (---) ?	.16 (.13-.19)
	56-96	6.6-8.4	1.19 (---) ?	.16 (.13-.19)
	96-152+	---	---	---
III	0-23	5.1-7.3	1.40 (---)	.14 (.11-.17)
	23-48	5.6-7.8	1.70 (---)	.09 (.07-.11)
	48-79	6.1-7.8	1.60 (---)	.03 (.01-.04)
	79-152+	7.9-8.4	---	.03 (.01-.04)
IV	0-23	6.1-7.3	1.36 (---)	.20 (.19-.21)
	23-104	6.1-7.8	1.39 (---)	.18 (.16-.20)
	104-152+	---	1.38 (---)	---

[a] Data obtained from:
Hutton, F.Z., Jr. and C.E. Rice. 1977. Soil Survey of Onondaga Co., New York. U.S. Dept. of Agric. Soil Conserv. Serv. Supt. of Documents, Wash.
Cline, M.G. 1960. Physical and chemical characteristics of New York soils. Dept. of Agron. Mimeo Series No. 60-3 Cornell Univ., Ithaca.

[b] Ranges not available.

Table 3. Average moisture retention and pore space data for Syracuse streetside soil groups.

Soil Group	Depth	Bulk Density	Total Pore Space	Soil water tension, bars					Available Water	Macro-pore Space
				0.1	1	3	5	15		
	cm	g/cc	cm^3/cm^3			cm^3/cm^3			cm^3/cm^3	cm^3/cm^3
I Thick Glacial Till Uplands	0-16	1.56	.42	.27	.24	.21	.17	.14	.13	.15
	16-54	1.81	.32	.25	.24	.21	.19	.16	.09	.07
II Thin Glacial Till Uplands	0-10	1.59	.40	.32	.28	.24	.21	.18	.14	.08
	10-35	1.84	.31	.26	.16	.14	.12	.11	.15	.05
III Glacial Outwash	0-12	1.61	.40	.29	.23	.18	.16	.13	.17	.11
	12-38	1.87	.29	.27	.22	.19	.17	.14	.14	.02
IV Alluvium	0-12	1.54	-	-	-	-	-	-	-	-
	12-38	1.71	.36	.34	.31	.30	.26	.22	.11	.02
V Made Land	0-10	1.73	.35	.26	.23	.21	.18	.10	.10	.09
	10-35	1.81	.32	.27	.24	.18	.12	.09	.18	.05

content. Rough estimates indicate that the surface values are one to two percent too high, and that subsoil values are about one-half to one percent too high. Considering this adjustment, the values are still one to two percent greater than those found in natural soils of central New York (Arnold, 1968). This observation confirms that of Patterson (1976) in urban soils of Washington, D.C.

Bulk Density

The bulk density values for streetside soils given in Table 1 are greater than those of natural soil profiles (Table 2), confirming observations made by others that urban soils may exhibit some degree of compaction for various reasons. The soil textures of central New York natural soils center on loan, silt loam, clay loam or very fine sandy loam all of which are susceptible to compaction. The bulk density values for the streetside soils are about the upper limit of the range of natural soil bulk density values (Group I, Table 2). It is possible that like values would be observed in pastures on similar soils.

The surface bulk density values of the five soil groups, except madelands, indicate that root penetration would be moderately inhibited. The 1.73 g/cc average value for urban madeland indicates that root penetration would occur with some difficulty. It is reported that bulk density of 1.68 g/cc may seriously inhibit root penetration (Patterson, 1976), unless previously formed channels are present. Although the subsoil bulk density values exceed 1.68 g/cc, roots were observed in structural fractures, or in old root or fauna channels. Most roots were observed in the surface 35 to 40 cm portion of the profiles.

Vibration by frequent heavy vehicle traffic may be a contributing factor to the high bulk density values of these soils. Ground vibration was observed on numerous occasions during field sampling. When this event occurs while the soil is saturated, or nearly so, partial disruption of aggregates and repacking of the primary soil particles could take place, increasing the bulk density. However, we have no direct measurement of this effect. Compaction by foot traffic would be confined to the surface layers and is probably minimal except for sites in the central business district.

Macropore Space and Aeration

Macropores are the largest pores in the soil material and are defined as those pores having a diameter greater than 0.03 mm, and are air-filled within 48 hours af'ter a saturated soil has been allowed to drain. As bulk density increases, or upon compaction, total porespace is reduced usually at the expense of macropore space. In some situations, disturbance to a soil may not reduce total pore space, but reduce macropore space causing a shift in the proportion of macropores to micropores. Most of the water stored in the soil occurs in the micropores. Gaseous diffusion is unable to occur in water-filled pores for all practical purposes, and so the macropores are those in which diffusion of oxygen into the soil and carbon dioxide out of the soil and into the atmosphere occurs.

Table 3 shows surface soil average macropore space ranged from .09 to .15 cm3/cm3 and that of subsoil ranged from .02 to .07 cm3/cm3. If .20 cm3/cm3 air space is required for adequate gaseous exchange between the soil and atmosphere (Bakker, 1970; Kramer, 1950), many of these streetside soils will exhibit restricted aeration even at field capacity. The problem is most acute in the subsoil.

Restricted aeration caused by soil compaction also implies an influence on the composition of the soil atmosphere. Reduced gaseous diffusion increases the carbon dioxide concentration and decreases the oxygen concentration. Carbon dioxide increases due to its production by root and microorganism respiration while oxygen is decreased by organism utilization and from the lack of resupply through diffusion from the atmosphere. Root elongation is inhibited at low oxygen and high carbon dioxide concentrations (Hopkins and Patrick, 1969), which would be expected in these subsoils. Tackett and Pearson (1964) studying cotton roots found the critical bulk density for adequate gaseous diffusion to be about 1.60 g/cc. Bulk densities greater than this value had little effect on further changes in oxygen or carbon dioxide concentrations, and therefore, impedence to root elongation became the primary factor.

Available Water

Available water is that water held in the soil against the force of gravity, but not so tightly that tree roots cannot absorb it. Available water is held in the soil with a force that ranges from 0.1 to about 15 bars. The water held with less force within this range is more available to the root. Hence, water held at .08 bars is more available to the root than that held at 5 bars.

The surface soil available water averages from .10 to .17 cm3/cm3 and subsoil average values range from .09 to .18 cm^3/cm3 (Table 3). It should be noted from comparing data in Table 2 that the streetside soils have available water values that are not significantly different from those of the natural soils. This confirms the earlier statement that the proportion of micropores or water filled pores is greater in the streetside soils with the greater bulk density values, since it would be expected that soils with greater bulk density would have less available water. The ideal medium-textured soil with a bulk density of 1.33 g/cm3 would have a total pore space of .50 cm3/cm3 of which .25 cm3/cm3 is air-filled porespace (macropores) and about .20 cm3/cm3 as available water. The remaining .05 cm3/cm3 consists of micropores, but water contained therein is held with a force exceeding that exerted by tree roots. Thus, the available water of the streetside soils is less than that of the ideal medium-textured soil.

CONCLUSIONS

It is apparent streetside soil properties provide root-growing conditions that are characterized by low air filled porespace and available water, causing periods of restricted aeration or periods of limited water availability at different times during the year. The situation may be succinctly stated as being too much water in the dormant season and early spring and too little water in late summer and early fall for optimum growth of roots. The proportion of the profile exhibiting these conditions very much depends, on many sites, upon the depth of disturbance or modification of the soil profile caused by urban development.

Tree species adapted to the extreme stresses must be planted on these soils, or the soil properties modified in some way to provide more favorable growing conditions for tree species not adapted to the present ones.

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