SOIL AND TREE RESOURCE INVENTORIES FOR CAMPUS LANDSCAPES

by P.D. Kelsey and R.G. Hootman

Abstract. A soil resource and tree inventory of the Northwestern University, Evanston, Illinois campus was undertaken to develop management strategies for maintaining maturé oak groves in an urbanized environment. The inventory used biological, physical, and chemical methods to evaluate the campus landscape. This integrative approach provides a comprehensive landscape evaluation as the basis for long-range planning.

Résumé. Un inventaire des arbres et des sols de l'Université Northwestern, Evanston, Illinois, fut réalisé afin d'élaborer des stratégies d'aménagement des forêst de chênes à maturité dans un environnement urbanisé. L'inventaire a intégré des méthodes biologiques, physiques et chimiques pour évaluer la végétation du campus. Cette approche intégrée procure une évaluation détaillée du terrain servant de base pour une planification à long terme.

Tree inventories are widely used in cities, parks, and campuses to identify the number and types of trees in a given area. Inventories also include physical aberrations, defects, diseases, or insect pests. Data from such inventories are used to plan the future management of the trees. Tree inventories usually include the following information: species, location, dbh, and general condition of the tree (2). Green (4) used a condition class to categorize the health of the plant in terms of its potential longevity. Rhizosphere conditions are rarely addressed in these inventories. Information on soil conditions is either absent or represented only by fertility recommendations (5).

A soil resource inventory (SRI) is generally used for facility siting, agronomic planning, and forest site planning. Use of SRIs in urban land planning is generally related only to site engineering. Soil resource inventories for managing urban development in remnant woodlands have been used in order to determine both physical and chemical consequences of proposed actions (6). Bulk chemical characterization is a useful tool in agronomic situations where the soil type is known as well as is the crop's response to fertilization (12). In urban situations, the soil system is usually physically disturbed, compacted, or chemically altered (9, 10). Standard soil survey is highly ineffectual in these situations because of the high degree of physical and chemical variability (10, 11).

Planning and maintenance of a park or campus tree canopy needs to be part of a long-term process, as the replacement of mature trees requires decades for most species. The trees that are planted today will contribute to the future aesthetic and functional attributes of the canopy. Thus, a monoculture planting of Norway maple *(Acer platanoides)* underneath the canopy of a former oak savanna will yield a forest devoid of oaks as they senesce and die. This is a common problem in the northeastern Illinois region. Planning the future tree canopy requires more than determining placement of various species. In urban settings, tree placement must take into account above ground and underground utilities, space for root development, drainage, and soil physical and chemical properties (9, 11, 13).

Materials and Methods

The Northwestern University campus is located on the shore of Lake Michigan in Evanston, Illinois. Three inventory units totaling approximately 30 acres were chosen on the campus. Each of the inventory units has an established oak grove that is now in a state of decline. This decline prompted Northwestern University officials to request a long-term management program to prolong the oaks' lives. Soil and tree resource inventories were methods used to establish a management plan.

Tree Inventory. During the summer of 1987, the trees in each unit on campus were identified, measured for dbh, examined for health problems, located on a map, and numbered sequentially with aluminum tags. The trees were also rated for species, location, and condition (2, 4).

The species rating is relative, based upon other species. It evaluates a species' individual characteristics such as hardiness, strength, life expectancy, insect and disease resistance, and aesthetics (2). The location classification is based upon the site of the tree, the placement of the tree, and the tree's function in the landscape (2).

The condition classification (Table 1) rates a tree's general physical conditon. This provides an indication of the tree's size, health, and expected longevity as modified from Green (4).

Table 1. Condition classification ratings

Class	Description
1	Newly planted; not established, but is expected to live a long time.
2	Established tree that is not of mature size, but is expected to live a long time.
3	Mature tree that is expected to live at least 15 years.
4	Mature tree that has such a severe limiting factor that death is expected within 15 years regardless of treatment. Treatment may be warranted to prolong tree life.
5	Mature tree that is dead or nearly dead and is considered hazardous. Immediate removal is recommended.
6	Newly planted, but has a severe limiting factor such that treatment may be needed to avoid premature death.
7	Established tree, not of mature size, that has a severe limiting factor and needs treatment to avoid premature death.
8	Mature tree that has a limiting factor which requires treatment to prolong life more than 15 years.
9	Mature tree that is so near death that treatment is not recommended and is considered a poor allocation of time and money. Immediate removal is recommended.

Inventory results were entered into a database file and sorted by species. In this way, the most common or repetitive species on campus could be identified. A management scheme was then developed based upon the species count, so that the repetitive planting of a species could be slowed or phased out and a more diverse planting scheme developed.

Eleven chlorotic trees were sampled for foliage analyses in mid-summer. The nutrient contents were compared to those of ten healthy trees of the same species on campus, and to literature on the same species (7). Foliage samples were tested for nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), boron (B), zinc (Zn), manganese (Mn), iron (Fe), and copper (Cu).

Soil Resource Inventory. Soil sampling sites were chosen in each unit to assess soil conditions and changes. Each site was located on a map. Soil samples were gathered using a 6.5 cm diameter soil auger. Most of the soil samples were gathered at the surface (0-7.5 cm and 7.5-15 cm). This is where most of the fine woody roots are located (15).

At several sites, soil samples were gathered at depths of 0-10 cm, 20-30 cm, and 50-60 cm. Sampling was extended to 60 cm because this approximates the maximum zone of soil development in the undisturbed soils on campus, and it is generally considered the maximum depth of most woody plant roots (14).

Soil factors most often associated with tree decline were identified in the field during sampling. Macronutrient chemical characterizations were performed in the laboratory.

There were too many declining trees for soil samples to be gathered at each one. However, the soil sampling network was intensive enough (an average of 2.5 soil cores per acre) that tree data could adequately be compared to soil data gathered nearby.

Results and Discussion

Tree Inventory. In the three units of study, 947 trees were inventoried representing 32 genera and 62 species (Table 2). Cultivars were not determined.

Aged, mature oaks (24.3%) dominate the landscape in all three units, yet youthful maples (36.3%) are the most abundant plants on the landscape. Seventy-two percent of the newly planted or immature (class 1 and 2) trees are maples, the future tree canopy of the campus (Table 2). Of this total, 66% are sugar maples *(Acer saccharum)* and Norway maples, and 6% are other maple species. Hence, the campus is not likely to have any oak openings left as the oaks die.

In the oak groves, native co-dominant and understory trees are absent. This seems unusual because as oak groves become developed environments, some individuals of other species usually survive. Notable for their absence are black walnut *(Juglans nigra)*, ironwood *(Ostrya virginiana)*, and hickories (Carya spp.).

Class 3, the current canopy trees which are in good condition, contains the largest number of trees (421 or 44.4%) of any class in the survey areas (Table 2).

The 30 young, struggling trees of class 6 (3.2%) will be part of the future canopy, should they survive. For planning purposes, one may

Table 2. Condition class frequencies

	Condition class									
Genus species	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*Total*
Abies concolor								2		2
Acer x freemanii			1					1		2
Acer ginnala			4					1		5
Acer negundo		1	1	1						3
Acer nigrum		4								4
Acer platanoides	8	44	60			1	6	4		123
Acer rubrum		3	4	1		6	34	2	1	51
Acer saccharinum		2	15	1				7		25
Acer saccharum	22	43	43	2	1	3	8	5	2	129
Aesculus hippocastanum			2	1		1				4
Ailanthus altissima			1							1
Alnus glutinosa			1							1
Betula nigra						2				2
Betula papyrifera			1							1
Carpinus caroliniana			1							1
Catalpa speciosa			2							2
Celtis occidentalis	1	6	18				4			29
Cercis canadensis		1		2						3
Crataegus sp.			22	3			7		1	33
Euonymus sp.			2	1						3
Fraxinus americana			3							3
Fraxinus excelsior 'Hessei'		1		1			1			3
Fraxinus pennsylvanica		5	20	1		1		13	1	41
Ginkgo biloba			2							2
Gleditsia triacanthos	1	5	21				6	5	1	39
Juglans regia			1	1				1		3
Juniperus communis			1							1
Juniperus sp.			2							2
Juniperus virginiana				2					3	5
Lonicera maackii			1					1		2
Magnolia acuminata		2								2
Malus sp.	1		7			5				13
Picea glauca			4	2						6
Picea pungens		1	4	3				1	1	10
Pinus nigra				10				1		11
Pinus strobus	4					5			1	10
Pinus sylvestris		4		1						5
Populus deltoides			3							3
Prunus americana			1							1
Prunus nigra		1	1				1			3
Prunus serotina			1							1
Prunus sp.								1		1
Quercus alba			37	14	1			49	1	102
Quercus x bebbiana			5					5		10
Quercus bicolor			2			1		1		4
Quercus ellipsoidalis	1	1	1							3
Quercus macrocarpa		3	38	1		1		19		62
Quercus palustris		1				4	1			6
Quercus rubra			15	6	1		2	15		39
Quercus velutina				3				1		4
Robinia pseudoacacia				5						5
Salix alba		5								5
Salix nigra				4	1					5
Sorbus aucuparia			3							3
Syringa pekinensis			4	2				2		8

Table 2.

	Condition class									
Genus species	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*Total*
Taxus sp.				2						2
Tilia americana	1	1	18	1			2	3	1	27
Tilia cordata			1							1
Tilia x euchlora			3							3
Ulmus americana		4	39	5			2	7		57
Ulmus pumila			5	1				4		10
Ulmus rubra				1						1
Total	39	138	421	77	4	30	74	151	13	947
Percentage	4.1	14.6	44.4	8.1	0.5	3.2	7.8	15.9	1.4	

assume a 50% loss. A large portion of these trees are young maples, crabapples, and white pines *(Pinus strobus)* (Table 2).

Approximately 8% of the trees in the survey are in class 7 (established trees with severe limiting factors) with red maple *(Acer rubrum)* representing 46% of this class (Table 2). A 50% loss can be expected for class 7 trees. This situation can be somewhat modified by arboricultural maintenance of individual trees. Though somewhat costly, these procedures will postpone removal and replacement costs.

A disturbing 16% of the inventory (151 trees) are mature declining trees (class 8). Ninety trees (60%) in this class are oaks, including 49 white oaks. Again, 50% loss can be expected over the next 15 years, which means loss of the oak dominance in the campus landscape.

Eight percent of the trees inventoried are in the severely declining class 4 (Table 2). White oak is the most numerous in this class followed by Austrian pine *(Pinus nigra),* red oak *(Quercus rubra),* black locust *(Robinia pseudoacacia),* and American elm *(Ulmus americana),* respectively.

Class 5 represents dead or nearly dead trees; as hazards they require immediate removal (Table 2). Another 13 trees, in Class 9, are mature trees near death which should be removed and replaced. These two classes are only 1.9% of the trees.

Based upon Table 2, at least 95 trees are dead or will die soon (classes 4, 5, and 9). Also 50% of the trees in classes 6, 7, and 8 (128 trees) will be lost within the next 15 years, for a total of 223, or 15 trees per year to replace.

A comparison of classes 3, 4, and 8 with classes 1 and 2 shows that classes 3, 4, and 8 have 212 oaks while classes 1 and 2 (their replacements) have only 6 oaks and 127 maples. To maintain the "oak grove" appearance, an oak regeneration project would be needed, plus an effort to reduce the number of Norway and red maples. Replacement species should include native oaks and diverse understory species suited to the urban environment.

The oak groves on campus are in a lawn which undoubtedly competes with the tree roots for moisture and nutrients (3, 16). The replacement of so large a lawn with mulch is not feasible. Mulching could be implemented on individual trees or small groups. Other sites could use another, less competitive groundcover in place of the lawn.

Since elms make up 7% of the inventory, a Dutch elm disease monitoring program should be implemented, along with other arboricultural practices, to monitor the health of susceptible elms.

Foliage Nutrient Analyses. Several of the trees are afflicted with a common problem with trees in urban areas, namely interveinal chlorosis: red maple, sugar maple, white pine, white oak, bur oak (*Quercus macrocarpa),* pin oak *(Quercus palustris),* and red oak.

Many trees develop chlorosis because disturbance around them changes the soil chemistry. Other trees develop chlorosis because they are planted where they are ecologically ill-adapted. Pin oak and red maple are very intolerant of alkaline soils, common to disturbed urban areas. They usually develop chlorosis, often severe, and may not reach maturity. The best management technique for these two is not to plant them. The white, red, and bur oaks on campus developed chlorosis over the years because the original soils have been gradually alkalinized.

The chlorosis on the Northwestern University campus is mainly from manganese deficiency, a macronutrient excess, or both. Decision as to whether the nutrient values for selected trees identified in Table 2 were deficient or excess is based upon comparison with values for green trees sampled and upon reference to literature about these species (7). Manganese deficiency chlorosis occurred in red and sugar maple, and white and red oak. An exceess of potassium occurred in some chlorotic white and red oaks.

Soil Resource Inventory: Physical Properties. Northwestern University's campus soils formed in water-deposited and aeolian-deposited sands. The surface soil of relatively undisturbed areas, such as the oak groves, consists of 12.5 cm to 25 cm of loamy materials over sandy loam grading to loamy sand and sand. Pure sand or sand and gravel are generally encountered below 45 cm. All the soils are well drained to excessively drained.

Sandy soils on this site are droughty and have lower nutrient bioavailability than finer-textured soils. The A horizon, the most organic portion of the soil, is generally 10 cm to 20 cm deep and is very important to the health of a tree. It is the most enriched zone of the soil profile, aeration is at a maximum, and moisture is generally most plentiful.

Near sidewalks, streets, and buildings the soils are disturbed and generally contain gravel or cobbles at or near the surface. The texture of these fill soils is gravelly loam or clay loam over gravelly loam.

On some areas of campus, the trees have little or no basal flare. On these areas, fill was placed over the original soil surface. On other areas, soils have been compacted by foot and vehicular traffic. Tree roots are typically damaged by both of these situations. Compacted areas should be loosened and traffic restricted.

Soil Resource Inventory: Chemical Properties.

Table 3. Foliage nutrient analyses of selected trees

	%					ppm				
C/G	*N*	*P*	*K*	*Mg*	*Ca*	*B*	*Zn*	*Mn*	*Fe*	*Cu*
Acer rubrum										
C	1.88	0.17	0.57	0.38	0.70	34	46	5*	127	9
C	1.58	0.15	0.65	0.31	0.72	35	42	4*	105	5
G	1.68	0.26	0.70	0.59	0.71	32	47	21	165	12
G	1.95	0.18	0.54	0.61	1.25	48	49	33	118	9
Acer saccharum										
C	1.87	0.21	0.88	0.32	1.64	68	39	13*	125	8
G	1.76	0.16	0.64	0.39	2.04	71	42	63	123	7
Quercus alba										
C	2.16	0.15	1.54#	0.29	0.52	69	40	13*	95	8
C	2.07	0.13	0.61	0.34	0.77	54	37	13*	92	9
G	2.51	0.19	0.80	0.38	1.07	70	43	68	119	10
G	2.40	0.15	0.77	0.36	0.79	57	38	46	119	9
Quercus rubra										
C	2.35	0.18	1.36#	0.30	0.70	46	46	6*	115	10
C	2.22	0.16	0.78	0.40	0.75	60	41	10*	114	9
G	2.60	0.13	0.82	0.49	0.70	75	48	27	146	9
G	2.45	0.17	0.94	0.46	0.75	72	42	28	91	8

C/G denotes chlorotic or green foliage on the tree.
* denotes nutrient deficiency
# denotes nutrient excess

Soil pH gives a general indication of the soil chemical environment. Soil pHs between 5.5 and 6.5 are considered optimal for most nutrient availability to plants. In alkaline soils, micronutrients may be unavailable. Below pH 5.5, calcium or magnesium may not be available. Most of the pHs on the Northwestern University campus are neutral to alkaline, though some of the oak grove soils are acid (pH 5.9-6.7) in the upper 20 cm (Table 4). Disturbance and urbanization over the years have alkalinized much of the area. Soil alkalinity has two sources: dissolution of carbonate materials in situ and runoff that has been alkalinized by contact with concrete and other limestone surfaces. This may be a reason for chlorosis and dieback on many, even long-established, trees. Soils in disturbed areas or near sidewalks are the most alkaline (pH 7.4-8.3). Where sensitive species are planted in alkaline soil, acidification should be undertaken.

The soil surface contains the highest levels of organic matter. The decay of organic material adds valuable nutrients as well as promoting good aeration and water-holding capacity. Soil organic matter content on the Northwestern University campus is generally near 5% in the surface (Table 4), which is considered average (1).

Very high levels (>100 ppm) of magnesium are found in most surface soils on campus (Table 4). This is probably related to the soil parent material. In the man-modified soils, magnesium levels often exceed 800 ppm but these levels do not seem to be deleterious to the trees.

Certain areas of campus soil contain high levels of sodium (Table 4). The highest levels are adjacent to a major city street which receives deicing salt during the winter. In humid regions sodium normally leaches through most soils, but near roadways so much salt is added that annual leaching is inadequate.

Summary

A tree and soil resource inventory on the Northwestern University, Evanston, Illinois campus led

Table 4. Selected soil chemical properties

				ppm				
Site	*Depth (cm)*	*pH*	*%OM*	*P*	*K*	*Mg*	*Ca*	*Na*
Oak grove	0-10	6.4	2.7	144	89	170	1000	3
	20-30	6.4	1.5	84	52	130	650	2
	50-60	6.6	0.5	47	7	75	300	2
Oak grove	0.0-7.5	6.4	6.2	62	104	540	2550	11
	7.5-15.0	5.9	4.3	24	41	360	2000	13
Parkway	0.0-7.5	7.5	6.4	6	139	1200	3200	134
	7.5-15.0	7.4	4.7	4	79	1100	3300	280
Parkway	0.0-7.5	7.7	6.4	8	152	735	2900	590
	7.5-15.0	7.9	5.8	6	125	695	3050	620
Sidewalk area	0-10	7.8	1.9	30	102	275	1800	9
	20-30	7.6	2.3	30	32	220	1550	10
	50-60	7.7	2.1	38	33	250	1700	10
Building area	0-10	7.6	4.2	11	76	570	2400	4
	20-30	8.0	2.9	7	47	415	2500	5
	50-60	8.1	1.7	12	18	245	1550	4

%OM denotes percent organic matter.

to management strategies for mature, declining, oak groves on campus. The incorporation of soil data with tree inventory data allows for long-term planning.

Decline of the oak groves and other trees is largely due to anthropogenic soil disturbance, especially compaction by foot and vehicular traffic, addition of fill, and alkalinization by runoff from concrete or limestone structures.

The young trees to replace declining oaks are mostly maples, many of which are poorly adapted to the urban environment. The recommendations for campus plantings include native species tolerant of urbanizing environments, with oaks and native understory plants to retain the natural oak grove appearance. To minimize soil disturbance, the sensitive oak groves should be restricted from all traffic. Soil should be acidified to alleviate alkalinity-induced chlorosis and mulch should be added as a soil amendment to reduce lawn competition.

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The Morton Arboretum
Urban Vegetation Laboratory
Lisle, Illinois 60532