THE NEW YORK BOTANICAL GARDEN
HEMLOCK FOREST PROJECT

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The history of the forest of the New York Botanical Garden is indeed prestigious (Irwin, 1979). The persistence of this 40-acre ecosystem along the Bronx River gorge has been a phenomenon of adaptation and survival to a harsh environment. Through the 1800's the forest was privately owned by the Lorillard family and remained "undisturbed" until its acquisition by the New York Botanical Garden at the turn of the century. Over the past 80 years the forest, once predominated by _Tsuga canadensis_, has managed to survive as the last remaining virgin stand in New York City. Considerable hardwood invasion and an absence of _T. canadensis_ regeneration (Dohrenwend, 1973; Bridges, 1975) have generated much concern about the vigor of the forest ecosystem (Irwin, 1979).

Recent studies of the geology and soils of the 40-acre tract have revealed the forest substrate as a precarious complex (Tornes, 1974; Glenn, 1978). Shallow, dry soils predominate over bedrock formations that outcrop frequently in the forest. Mean precipitation and temperature averaged 42.37 in. and 54.5°F respectively.

The initial thrusts of the staff involved regeneration of _T. canadensis_ within the forest stand. From 1896 to 1927 numerous notes and articles appeared in the Botanical Garden technical literature that detailed regeneration and _T. canadensis_ life history data. These studies and others will be reviewed in Part II of this report.

Concern for revitalization of the forest surfaced again in the early 1970's. Forest surveys, _T. canadensis_ inventories, water quality studies and soil and geology investigations were evidence of efforts to understand and form management objectives for the forest. Many innovative short-term plans have been formed and generally involved restricting human access and recreating the *T. canadensis* community.

In a broader context, Egler (1968) found the plight of the Botanical Garden forest a "challenge for survival." He felt the crisis of dense human populations, living in degraded environments, "demands an enlargement of the perspectives of all our social institutions, including botanical gardens..." Egler foresaw an interactive center "that would not only serve the residents of and visitors to the world's greatest city, but one that would become a model for other centers around the world." To the extent that any management objectives can be considered, ecological data revealing the interacting compartments of the forest ecosystem must be known.

The objectives of the study were to:

1. Produce a pre-study synopsis of the history of the Hemlock Forest. This report will include appropriate geologic, edaphic and climatic information, a summary of qualitative and quantitative studies of the flora and fauna, and the chronology of management policies that have governed activities in the forest.
2. Inventory the flora of the Hemlock Forest. These quantitative data will be compared with historical information to determine the pattern of vegetation succession in the Forest.
3. Inventory the fauna of the Hemlock Forest and adjacent Rock and Native Plant Gardens with emphasis on damaging mammal populations.
4. Produce a series of management alternatives for the Hemlock Forest.

Specific alternatives for controlling damaging mammal populations will also be presented.

The presentation of the products for each objective has been designed in a two-part final report. The first portion presents the data generated over the entire forest stand and proposes several recommendations for revitalizing the forest system. Part II will review the life history and management of *T. canadensis* and present the results of intensive data generated on 6 selected sites containing *T. canadensis*. Various types of soil, vegetative and mammal population data will be analyzed and used to interpret the relative vigor and potential for managing the forest ecosystem.

We acknowledge the financial support graciously given by the Eppley Foundation for Research. We thank Mr. Arthur Ode and Mr. John Reed of the Garden staff for administrative and logistical support. Mr. Michael Ruggiero and students from the New York Botanical Garden School of Horticulture provided field assistance and encouragement. Mr. Ray Winchcombe, Mr. William Lizotte, and Mr. Cosmo Costa of the Cary Arboretum participated in various portions of the field and laboratory work. Last but not least we thank Ms. Julie Morgan for editing and typing the manuscript.

Methods and Materials

Soil and vegetation data were collected between June 25 and September 30, 1980. A grid system composed of cells 30 x 30 m was used to locate 157 intersection points (Fig. 1). Each point was the center for a 5 m diameter sample plot.

Litter depth and soil samples were taken at 4 points located 5 m north, east, south and west of the plot center. Soil samples were collected from the upper 6 cm of soil by inserting a steel tube (1.5 cm x 15 cm). The 4 soil samples obtained from each plot were thoroughly mixed and totaled a maximum of 30 g. A 5 gm subsample was used to determine soil organic matter by weight loss after ignition in a blast furnace (Wilde et al., 1972). Soil pH was determined using a 5 gm subsample and a laboratory pH meter. Samples were mixed for 5 minutes, then slowly stirred (to maintain particle suspension) for 90 seconds after which 3 pH readings were taken. The average of the 3 readings constituted the value for the sample plot.

Leaf litter was measured prior to soil sampling at the 4 points described above for each plot. A metric rule was pushed through the litter to the mineral soil surface. The plot value was determined by averaging the values obtained from the 4 sampling points.

Herbaceous vegetation was identified and a sketch of the distribution of each species was recorded for all plots. All woody stems were identified and the number of stems of each species recorded on each plot. The DBH (diameter at breast height) was measured with a DBH tape for large trees and with calipers on small trees. Total height was determined with a clinometer (corrected for observer height and slope of terrain) for large trees and measured with a meter stick for small trees.

Results

Thirty woody plants were identified from the forest plots. A X^2 test of mutual independence (Pielou, 1974) indicated that all species did not occur independently of one another (X^2 = 37,601.48, 25 d.f, P <.001). The results of 2 x 2 contingency table comparisons of species (Pielou, 1974) indicated few significant plant groups occurred in the forest. Prunus serotina was positively associated with P. avium and Cornus florida (X^2 = 5.54 and 7.41, 1 d.f., P <.05). Weakly significant negative associations occurred between Tsuga canadensis and P. serotina, P. avium and Carya glabra (X^2 = 3.64, 3.52, 2.99, 1 d.f, P <.10).

An index of sociability (Whitford, 1949) was calculated for all species (Table 1). Two shrubs, Lindera benzoin and Viburnum dentatum, had high index values which reflected the occurrence of many aggregated clumps of individuals. Another shrub, V. acerifolium, was found very infrequently but in aggregations similar to L. benzoin and V. dentatum.

T. canadensis, P. avium, Fagus grandifolia and Acer rubrum had high index values but occurred in either infrequent yet dense groups (F. grandifolia) or frequently as individuals. P. serotina was more widely distributed in small groups. The remaining species were distributed singularly or in pairs and were infrequently encountered.

An importance index derived from volume and frequency data was used to approximate the total forest space occupied by each species (Table 2). Again, due to a wide distribution and dense growth pattern, L. benzoin filled twice as much space as any other single species. Trees with several large individuals replaced the shrubs in the index ranking (T. canadensis, F. grandifolia, Quercus borealis, Q. velutina). Liriodendron tulipifera had a relatively high index value yet occurred rarely as very large specimens.

To further isolate the degree of utilization of forest space for each species, importance index values were determined with an arbitrary stratification design (Table 3). Individuals were classed as seedlings (0-1m), saplings (1-5m), understory (5-10m), co-dominant overstory (10-25m) and dominant overstory (25-50m).

The 0-1m stratum was predominantly _L. benzoin_ while _P. serotina_ and _V. dentatum_ were strong co-inhabitants. _V. acerifolium_ and 17 additional species occupied many small but widely distributed forest zones.

P. serotina and to a lesser extent _L. benzoin_ were major species in the 1-5m layer. _P. avium_, _V. dentatum_ and _Phellodendron amurense_ were less common. In all, 27 of the 30 total species occurred in this stratum.

A diverse group including _T. canadensis_, _P. serotina_, _A. rubrum_, _C. florida_, _V. dentatum_ and _P. avium_ were predominant in the understory layer. Also important were _Fraxinus americana_, _P. amurense_, _Ulmus americana_, and _F. grandifolia_

The major co-dominant overstory species was _T. canadensis_. Of the remaining 18 species _Q. borealis_ and _Betula lenta_ were the most common.

The dominant overstory was occupied by _L. tulipifera_ with _Q. velutina_ and _T. canadensis_ occurring less frequently. Only 6 species were encountered in this stratum.

Each population was characterized further by strata (Table 4) and by DBH class (Table 5). Based on the inspection of Tables 3, 4 and 5, each species was subjectively placed into a seral class (Table 6).

The summary of the leaf litter, soil organic matter and soil pH data indicated a wide range of values and a large sample variance existed for each parameter (Table 7). Linear regression analysis rejected the hypothesis that significant correlations occurred between combinations of the three variables. In addition, regression analysis failed to detect significant pattern relationships amongst the above 3 parameters and any of the forest trees and shrubs.

No soil or vegetation data were collected from 6 plots that were located on rock. Three additional plots were not found to contain woody stems. Sparse herbaceous ground cover was found on 35 plots and included 12 species. *Maianthemum canadense*, *Aster divaricatus*, *Poa spp.*, *Commelina virginica*, *Parthenocissus quinquefolia*, *Polygonatum spp.*, and *Rubus spp.* were most commonly observed.

Discussion

The New York Botanical Garden Forest exhibited an extremely heterogeneous array of biotic and edaphic conditions. Few associations of woody trees and shrubs were discovered in the X^2 analysis. P. serotina, a species tolerant of an open forest, frequently occurred with P. avium, a closely related species, and with C. florida, a species tolerant to intermittent forest cover. Correspondingly, P. serotina, P. avium and C. glabra were somewhat intolerant to the dense canopy of T. canadensis.

Synthesis of the indices of sociability and importance clearly depicted a continuum of species adaptations to widespread ecotypic differentiation. Several pioneer species characterized by narrow tolerances occurred in rare but dense aggregations (such as S. albidum and V. acerifolium). Alternatively several late successional species were found as rare individuals dispersed throughout the forest (such as L. tulipifera and Q. velutina). A large species group was termed transition and included a wide assortment of distributional patterns. A. rubrum, a tolerant species, occurred in the decreasing continuum of an established population. Q. borealis, Q. velutina, F. grandifolia, and B. lenta were found in somewhat disjunct distributions caused by differential temporal or spacial stress patterns. The majority of the transition species were found in low numbers, sporadically throughout the forest.

The wide variation in edaphic factors and the lack of correlation of any soil parameters to each other or to any species distribution suggests inconsistencies in the microhabitats of the forest. Field observations indicated the forest soil profile was poorly developed and in many locations had become a hardpan impervious to air and water. The combination of an extremely poor soil profile and the evident hardpan can lead to intense podzolization (acid leaching); severely limited microbial and invertebrate activity, and consequently, reduced rates of organic matter decomposition (Schlenker et al., 1969). During the 4 month field season, soil invertebrates were not observed and evidence of microbial decomposition was absent.

Podzolization was inevitable in moist, cool conditions (Spurr and Barnes, 1973) and led to slow organic matter decomposition and nutrient cycling (Spurr, 1952b). Nitrogen, which is taken up faster than other nutrient ions, is limited in coniferous forests and can become bound in the organic matter as leaf litter persists (Johnson, et al., 1980). A portion of the variability in leaf litter depth was felt, in this study, to be due to the lack of a developed soil horizon profile. The resulting gap promotes increased mobility of surface litter on the hardpan substrate.

Large organic debris such as fallen trees and limbs was absent from the forest floor. Daubenmire (1968) found such material was a long-term source of nutrients as well as a focal point for microbial, invertebrate and vertebrate species that contribute to the cycling of matter and energy in the forest ecosystem. Spurr (1952b) also found species such as T. canadensis reproduced in patterns closely correlated to the accumulation of large organic debris.

The forest has been occuppied by species that have out-lived the seral conditions that promoted their development and by species that may, in the absence of disturbance, approximate stability as the soil profile is allowed to readjust. The dominance of T. canadensis over the past 80-100 years has been characteristic of T. canadensis invasion or release in mature hardwood stands approaching senescence (Daubenmire, 1968). Under such conditions, soils decrease in fertility and become characteristic substrates for T. canadensis development (Daubenmire, 1968). The distribution of the T. canadensis population in Tables 4 and 5 followed a continuum pattern. The proportion of trees that have survived naturally and the success of several planting efforts have created a mixed T. canadensis population. Part II of this report will detail an intensive study of edapnic and biotic factors in a large aggregation of T. canadensis in the forest system.

The activities and mechanisms responsible for the condition of the forest are many and complex. Observations throughout the summer indicated human use of the forest was nearly continuous. Traffic was unregulated and hence, numerous uncharted footpaths and convenience trails appeared and disappeared. The hardpan condition of portions of the forest substrate described earlier has been undoubtedly created by years of compaction. Periodic upheavals of trees by wind or other causes have created small pockets where soils become exposed, nutrients are released, and pioneer or transition species are established.

The forest condition is one of serious ecosystem malfunction. A critical component of the mosaic of varying edaphic and biotic factors has been the suspected stagnation of fundamental nutrient cycling. The flow of energy through the various compartments of the forest ecosystem must be re-established to a position of relative stability. The forces of change and stability need to be evident but balanced. The dynamics of the forest must be accepted before management can proceed.

Clearly, climax is not real in the sense of a permanent, stable condition. Finally, ecological principles dictate that old patterns will not be recreated and that new patterns in response to new environmental conditions will develop.

The monitoring of selected edaphic and biotic parameters representing various segments of the energy cycle will be critical to understanding and evaluating progress toward any forest management objectives. The forest ecosystem is tremendously complex, but there are rich rewards to be won by gaining even a partial understanding. The formation and accomplishment of management objectives for the forest must be guided by such knowledge.

Recommendations

1. Establishment of a permanent grid system similar to that used in this study will be critical in evaluating future patterns of change in edaphic and biotic parameters. Great difficulty was encountered in attempts to correlate historical information to specific sites within the forest. Grid points should be located precisely with ordination to the United States Geological Survey system. Inconspicuous grid corner markers should be located in the substrate and be used as permanent plot centers.
2. Periodic collection of soil data including compaction, organic matter content and pH should be planned. Similarly leaf litter depth, species composition, stem frequency, DBH, and total height for woody plants and the abundance and distribution of selected invertebrate and vertebrate animals should be collected.
3. A study of the decomposition portion of the energy cycle of the forest should be undertaken. With that data and the data generated in this study, a model composed of selected parameters representing the various compartments of the energy cycle can be produced. After the input of data collected over a period of three years (starting from this project in 1980), advances toward the goal of revitalizing the forest as a complete and dynamic system can be measured. Using the model, a projected time schedule of sequential recovery stages can be prepared.

Paramount to the utilization of such management information is the understanding that the time schedule will be dictated by the forest ecosystem and the magnitude of internal energy input (manpower and materials).

Caution should be exercised over the extent of external input as many large patches of new environment can be created that will demand continual maintenance and produce several distinct ecotypes with each requiring a different management program. Initially well-planned and properly evaluated soil and water management may accelerate the process of reviving the forest energy cycle.

4. The value of a comprehensive management program that blends interpretation, education and research will be enormous. Given the small size of the forest, one coordinated plan will prevent site segretation and allow for more cost-effective management. Based on the present limits that exist within the forest ecosystem, the need for interpretation and education, the potential for acceptable research, and the magnitude of resources, a series of attainable management objectives should be formulated. If the forest is to be managed as a natural preserve, objectives should be dynamic, thus reflecting the forces of change and stability that exist in all ecosystems. The establishment of management goals rather than objectives demands a finite, exact set of conditions that define an endpoint. The history of man's conquest of ecosystems clearly depicts a continuous struggle to simplify ecosystems by sustaining an equilibrium. The maintenance of a precise esthetic condition requires the input of continual and ever-increasing amounts of energy to overcome the natural forces of change, adaptation and ultimately evolution. Given the prestigious history and site tenacity of the Botanical Garden Forest, management objectives that maximize understanding and adaptation and minimize external energy requirements would be

most appropriate.

5. The assessment of the limitations of management objectives would not be complete without a plan for regulating and controlling public access for interpretation and education and staff access for research and management. Steps have already been taken to define the magnitude of the public access problem. Several options for human management are outlined below.

   A) The entire forest can be fenced with raised boardwalks and controlled trails established. Fencing the extreme perimeter (approx. 7000 ft) and establishing gates and maintenance access roads should cost from $100,000 to $150,000 depending upon specifications. The maintenance of the fence and the essential installation and maintenance of perimeter buffer landscaped plants will be costly. Security would be required to monitor gates and fence lines. All types of access would be made on boardwalks, controlled trails or on majntenance roads. Minimizing the impact of construction and maintenance is essential. Maximizing the esthetic, interpretive, educational and research values of the forest is also essential. A broad spectrum program using signage, leaflets, guides, labeled specimens and display boards will prcmote understanding and respect for the forest as a system. This concept is much expanded in Section B of this recommendation.

   A fence such as outlined above has the potential to segregate this important component of the Botanical Garden, thus damaging the concept of an integrated plant sciences center and potentially alienating the public. In addition, the costs of interpretation, education, and management programs in the forest would be over and above the installation and maintenance costs of the fence.

B) A plan for forest access without a fenced perimeter will succeed only with a long-term commitment to the forest by the Garden staff. Realignment of trail systems to only one access point would be beneficial. The trail system should provide for adequate circulation, stimulating interpretation and, where appropriate, stations where group education activities can occur. Portions of the trail system should be either elevated as a boardwalk or contained by a 2-3 ft post and rail fence. Signage will be essential to informing the flow of users and for constantly deterring off-trail forays. Selected trails can be made sufficiently wide so as to allow maintenance and fire-control access yet serve as parts of the user trail system. Wood chips have been used successfully in many preserves as a biodegradable yet acceptable trail substrate. Gravel or paving should only be used with great caution as they require much greater installation and maintenance resources.

Research within the forest preserve beyond that essential for the management model should be allowed by special permit after submission of a proposal. Interpretation and education should convey the sensitive and complex nature of this forest and promote an understanding of an respect for the forest ecosystem. Species identification and the explanation of the role of various elements of the forest from microbial action in the leaf litter to the largest tree need to be integrated into a concept of a complex system at work. Display boards, smaller signs and specimen labels can go a long way toward this objective. Introductory and special instructions can be distributed from the main access point. Initially, guided tours may be necessary in changing the habits of past users and in turning away past abusers. As use becomes more controlled, self-guided tours (after a briefing at the main access point) may be possible.

Perimeter security will need to be rigid initially to insure the theme of "access with understanding" is transmitted to the public. Persons who abandon the trail system should be reprimanded to return to the trails, escorted from the forest, or in some cases forced to leave the Garden. In extreme cases, police action and prosecution may be necessary.

A major contribution toward security in the forest would be gained by better protection of the entire Botanical Garden perimeter. Fencing with appropriate boundary security and main gate control would achieve great progress in protecting the integrity of the Garden's resources and promoting the New York Botanical Garden as a unique and special contribution to the people of the metropolitan area. Uncontrolled public access has been considered an obligation of the Garden Forest. Public realization of the potential degradation of sophisticated ecosystems by limitless human use can be accelerated by offering the privilege of access with understanding.

Paramount to controlling public access is acceptance of the fact that abuse cannot be eliminated. In time, the commitment to and management of the forest preserve by the staff will be transmitted to the public via signage, trails, personal contact, and security. Progress in controlling public access will be measurable first by the level of staff participation in the continual process of planning, interpretation, education, research and management and second by the forest ecosystem itself.

Equally as important, adequate time must be allowed for this proposed alternative to develop in stages. In this way, each advance in attaining this objective can be used to guide successive efforts. The benefits in accomplishing such an alternative will be seen in public support both in spirit and in dollars for the Botanical Garden as a whole and the forest as a special element of this great complex.

Literature Cited

Bridges, J.T. 1975. The New York Botanical Garden Hemlock Forest fact sheet. Unpubl. mimeo, New York Bot. Garden Library, Hemlock Forest File. 2pp.

Daubenmire, R. 1968. Plant communities. Harper and Row Publ. Inc., New York. 300pp.

Dohrenwend, R.E. 1973. Hemlock problem - an assessment. Unpubl. mimeo, New York Bot. Garden Library, Hemlock Forest File. 2pp.

Egler, F.E. 1968. Memorandum to New York Botanical Garden Committee. Unpubl. mimeo, New York Bot. Garden Library, Hemlock Forest File. 3pp.

Glenn, W.H. 1978. Guide to geology: The New York Botanical Garden. The New York Botanical Garden, Bronx. 14pp.

Irwin, H.S. 1979. Sustaining the city's primeval forest. Garden 3(5):NYBG 1-3,7.

Johnson, D.W., D.W. Cole, C.S. Bledsoe, G. Carrol, K. Cromack, R.L. Edmonds, S.P. Gessel, C.C. Grier, B.N. Richards, J. Turner, and K. Vogt. 1980. Nutrient cycling in forests of the Pacific Northwest. In R.L. Edmonds, Ed., Analysis of coniferous forest ecosystems in the western United States. U.S./I.B.P. Synthesis Series. Dowden,Hutchinson and Ross,Inc., Stroudsburg, Pa.

Pielou, E.C. 1974. Population and community ecology. Gordon and Breach, Science Publ. Inc., New York. 424pp.

Schlenker, G., U. Babel and H.P. Blume. 1969. Untersuchungen uber die Auswirkungen des Fichtenreinanbaus auf Parabraunerden und Pseudogleye des Neckarlandes. VII. Zusammenfassung und Folgerungen fur die forstliche Standortsbeivertung. Mitt. Vereins Forstl. Stancortsk. Forstpflz. 19:111-114.

Spurr, S.H. 1952b. Forest inventory. Ronald Press Co., New York. 476pp.

Spurr, S.H. and B.V. Barnes. 1973. Forest ecology. Ronald Press Co., New York. 571pp.

Tornes, L.A. 1974. Soil survey of the hemlock forest at the New York Botanical Garden, Bronx, New York. Unpubl. mimeo, New York Bot. Garden Library, Hemlock Forest File. 20pp.

Whitford, P.B. 1949. Distribution of woodland plants in relation to succession and clonal growth. Ecol. 30:199-208.

Wilde, S.A., G.K. Voigt, and J.G. Iver. 1972. Soil and plant analysis for tree culture. 4th ed., Oxford and I.B.H. Publ. Co., New Delhi. 172pp.

Fig. 1. The grid system used from June-October, 1980, in the New York Botanical Garden forest. The corner of each grid cell served as the center for a 5 m diameter plot.

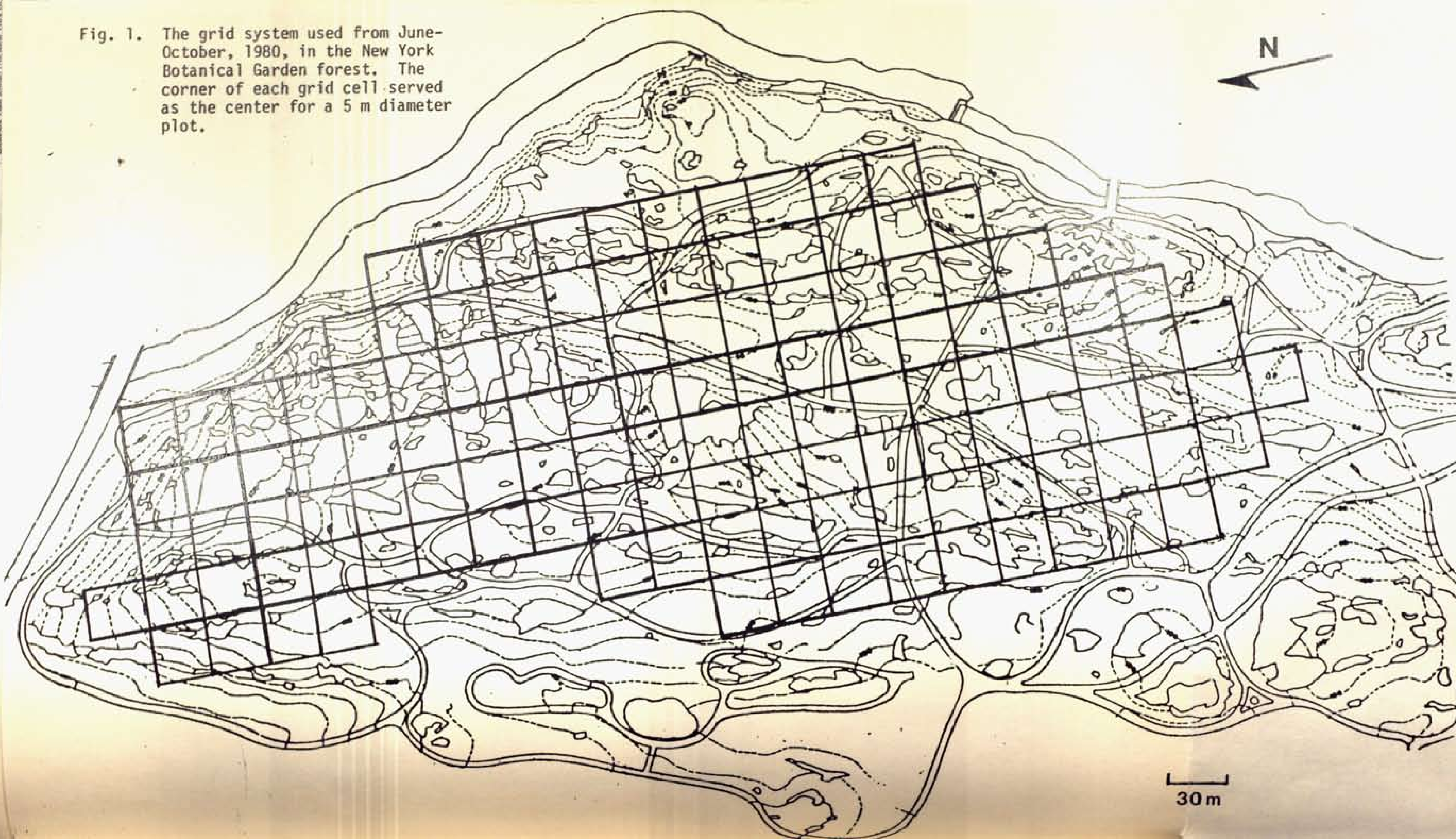

Table 1. Index of sociability as derived from density and frequency of woody plants in the New York Botanical Garden, Bronx, New York.

Species	Average Density per Plot	Plot Frequency (%)	Index of Sociability
Lindera benzoin	13.38	34.4	460.27
Viburnum dentatum	12.8	9.9	126.72
Prunus serotina	3.98	28.5	113.43
Tsuga canadensis	1.77	23.2	41.06
Prunus avium	2.71	13.9	37.67
Fagus grandifolia	5.00	6.0	30.00
Viburnum acerifolium	11.5	2.6	29.90
Acer rubrum	1.95	13.9	27.11
Aralia spinosa	6.8	3.3	22.44
Phellodendron amurense	1.55	13.2	20.46
Ailanthus altissima	5.6	3.3	18.48
Liquidambar styraciflua	2.7	6.6	17.82
Sassafras albidum	5.20	3.3	17.16
Fraxinus americana	1.44	11.9	17.14
Malus sp.	17.0	1.0	17.00
Quercus borealis	1.64	9.3	12.96
Acer saccharum	1.45	7.3	11.46
Quercus velutina	1.7	6.6	11.22
Cornus florida	1.33	7.9	10.51
Carya glabra	1.25	7.9	9.88
Ulmus americana	1.67	4.0	6.68
Liriodendron tulipifera	1.0	4.0	4.00
Betula lenta	1.2	3.3	3.96
Quercus alba	1.0	3.3	3.30
Carpinus caroliniana	2.0	1.3	2.60
Ostrya virginiana	1.5	1.3	1.95
Quercus palustris	1.0	1.3	1.3
Morus alba	1.0	1.0	1.0
Crataegus sp.	1.0	1.0	1.0
Magnolia virginiana	1.0	1.0	1.0

Table 2. Importance index as derived from volume and frequency of woody plants in the New York Botanical Garden, Bronx, New York.

Species	Total Volume (m^3)	Stem Frequency (%)	Importance Index
Lindera benzoin	133.37	42.35	5648.22
Viburnum dentatum	716.51	3.78	2708.41
Prunus serotina	46.79	10.36	484.74
Tsuga canadensis	147.78	2.74	404.92
Prunus avium	230.40	1.40	322.56
Fagus grandifolia	304.08	1.04	316.24
Viburnum acerifolium	112.89	2.50	282.23
Acer rubrum	19.78	11.70	231.43
Aralia spinosa	120.52	1.65	198.86
Phellodendron amurense	118.45	1.58	187.15
Ailanthus altissima	373.97	.37	138.37
Liquidambar styraciflua	36.40	3.47	126.31
Sassafras albidum	31.55	1.89	59.63
Fraxinus americana	65.05	.91	59.20
Malus sp.	57.08	.98	55.94
Quercus borealis	94.62	.37	35.01
Acer saccharum	28.98	.98	28.40
Quercus velutina	1.34	10.36	13.88
Cornus florida	46.27	.30	13.88
Carya glabra	21.42	.61	13.07
Ulmus americana	2.03	3.90	7.92
Liriodendron tulipifera	4.51	1.58	7.13
Betula lenta	4.01	1.71	6.86
Quercus alba	1.07	2.07	2.21
Carpinus caroliniana	13.62	.12	1.63
Ostrya virginiana	6.55	.24	1.57
Quercus palustris	7.24	.18	1.30
Morus alba	1.45	.06	.09
Crataegus sp.	.15	.06	.01
Magnolia virginiana	.21	.06	.01

Table 3. Importance index as derived from volume and frequency by forest strata of woody plants in the New York Botanical Garden, Bronx, New York.

Species	0-1m			1-5m			5-10m			10-25m			25-50m		
	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index	Vol (m^3)	Freq (%)	Imp Index
Prunus serotina	3.01	13.7	41.2	16.36	8.3	135.8	16.55	13.3	220.1	10,87	2.0	21.7	0	0	0
Tsuga canadensis	1.50	.7	1.1	6.54	1.3	8.5	31.47	10.8	339.9	553.11	36.7	20299.1	125.23	16.7	2091.3
Prunus avium	.77	3.5	2.7	9.46	3.2	30.3	12.52	8.4	105.2	13,65	1.0	13.7	0	0	0
Fagus grandifolia	.83	3.5	2.9	9.75	1.8	17.6	6.48	4.8	31.1	44.86	1.0	44.9	85.86	16.7	1433.9
Acer rubrum	.34	1.6	.5	7.64	1.8	13.8	20.75	7.2	149.4	84.16	10.2	858.4	0	0	0
Liquidambar styraciflua	.54	2.5	1.4	1.66	.6	1.0	3.39	1.2	4.1	45.96	3.1	142.5	68.98	8.3	572.5
Fraxinus americana	.22	1.0	.2	1.31	1.0	1.3	10.36	6.0	62.2	106.56	6.1	650.0	0	0	0
Sassafras albidum	.75	3.5	2.6	1.09	.1	.1	2.66	1.2	3.2	0	0	0	0	0	0
Quercus borealis	.13	.6	.1	2.04	.9	1.8	6.33	3.6	22.8	174.38	8.2	1429.9	47.52	8.3	394.4
Cornus florida	.03	.1	< .1	7.66	.9	6.9	16.89	8.4	141.9	4.40	1.0	4.4	0	0	0
Acer saccharum	.03	.1	< .1	2.74	1.0	2.7	3.27	3.6	11.8	51.04	4.1	209.3	0	0	0
Carya glabra	.12	.4	< .1	1.38	.5	.7	2.21	1.2	2.7	61.35	7.1	435.6	0	0	0
Quercus velutina	.04	.1	< .1	1.84	.6	1.1	2.00	1.2	2.4	133.89	8.2	1097.9	166.31	16.7	2777.4
Ulmus americana	0	0	0	.50	.8	.4	11.34	3.6	40.8	9.58	1.0	9.6	0	0	0
Betula lenta	.03	.1	< .1	.69	.1	.1	0	0	0	93.89	4.1	384.9	0	0	0
Quercus alba	.03	.1	< .1	.89	.3	..3	0	0	0	45.35	2.0	90.7	0	0	0

Table 3 (cont.)

Species	0-1m Vol (m³)	0-1m Freq (%)	0-1m Imp Index	1-5m Vol (m³)	1-5m Freq (%)	1-5m Imp Index	5-10m Vol (m³)	5-10m Freq (%)	5-10m Imp Index	10-25m Vol (m³)	10-25m Freq (%)	10-25m Imp Index	25-50m Vol (m³)	25-50m Freq (%)	25-50m Imp Index
Carpinus caroliniana	0	0	0	2.05	.4	.8	4.50	1.2	5.4	0	0	0	0	0	0
Liriodendron tulipifera	0	0	0	0	0	0	0	0	0	52.55	2.0	105.1	321.42	333	10703.3
Ostrya virginiana	0	0	0	.21	.1	< .1	7.03	2.4	8.4	0	0	0	0	0	0
Quercus palustris	0	0	0	0	0	0	1.95	1.2	2.3	11.67	1.0	11.7	0	0	0
Morus alba	0	0	0	.21	.1	< .1	0	0	0	0	0	0	0	0	0
Crataegus sp.	0	0	0	.15	.1	< .1	0	0	0	0	0	0	0	0	0
Magnolia virginiana	0	0	0	1.45	.1	.1	0	0	0	0	0	0	0	0	0
Lindera benzoin	7.43	34.5	256.3	1.26	59.9	75.5	0	0	0	0	0	0	0	0	0
Viburnum dentatum	3.18	14.9	47.4	1.98	10.1	20.0	6.86	15.7	107.7	0	0	0	0	0	0
Viburnum acerifolium	1.98	9.3	18.4	.05	.1	< .1	0	0	0	0	0	0	0	0	0
Phellodendron amurense	.42	1.6	.7	13.33	1.9	25.3	10.0	4.8	48.0	7.81	1.0	7.8	0	0	0
Aralia spinosa	1.07	5.0	5.4	0	0	0	0	0	0	0	0	0	0	0	0
Ailanthus altissima	.57	2.7	1.5	3.44	1.3	4.5	0	0	0	0	0	0	0	0	0
Malus sp.	0	0	1.34	2.2	2.9	0	0	0	0	0	0	0	0	0	0

Table 4. Percent and total number of stems (N) by forest strata of woody plants in the New York Botanical Garden, Bronx, New York.

	0-1m	1-5m	5-10m	10-25m	25-50m
Species	% - N	% - N	% - N	% - N	% - N
Prunus serotina	54 - 93	38 - 64	7 - 11	1 - 2	0
Tsuga canadensis	8 - 5	16 - 10	15 - 9	58 - 36	3 - 2
Prunus avium	42 - 24	44 - 25	12 - 7	2 - 1	0
Fagus grandifolia	53 - 24	31 - 14	9 - 4	2 - 1	4 - 2
Acer rubrum	27 - 11	34 - 14	15 - 6	24 - 10	0
Liquidambar styraciflua	63 - 17	18 - 5	4 - 1	11 - 3	4 - 1
Fraxinus americana	27 - 7	31 - 8	19 - 5	23 - 6	0
Sassafras albidum	92 - 24	4 - 1	4 - 1	0	0
Quercus borealis	18 - 4	30 - 7	13 - 3	35 - 8	4 - 1
Cornus florida	6 - 1	44 - 7	44 - 7	6 - 1	0
Acer saccharum	6 - 1	50 - 8	19 - 3	26 - 4	0
Carya glabra	20 - 3	27 - 4	7 - 1	46 - 7	0
Quercus velutina	6 - 1	29 - 5	6 - 1	47 - 8	12 - 2
Ulmus americana	0	60 - 6	30 - 3	10 - 1	0
Betula lenta	17 - 1	17 - 1	0	66 - 4	0
Quercus alba	20 - 1	40 - 2	0	40 - 2	0
Carpinus caroliniana	0	75 - 3	25 - 1	0	0
Liriodendron tulipifera	0	0	0	33 - 2	67 - 4
Ostrya virginiana	0	33 - 1	67 - 2	0	0
Quercus palustris	0	0	50 - 1	50 - 1	0
Morus alba	0	100 - 1	0	0	0
Crataegus sp.	0	100 - 1	0	0	0
Magnolia virginiana	0	100 - 1	0	0	0
Lindera benzoin	34 - 234	66 - 461	0	0	0
Viburnum dentatum	53 - 101	40 - 78	7 - 13	0	0
Viburnum acerifolium	98 - 63	2 - 1	0	0	0
Phellodendron amurense	36 - 11	48 - 15	13 - 4	3 - 1	0
Aralia spinosa	100 - 34	0	0	0	0
Ailanthus altissima	64 - 18	36 - 10	0	0	0
Malus sp.	0	100 - 1	0	0	0

Table 5. Percent and total number of stems (N) by DBH classes of woody plants in the New York Botanical Garden, Bronx, New York.

DBH (cm)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11
Species	%-N	%-N	%-N	%-N	%-N	%-N	%-N	%-N	%-N	%-N	%-N
Prunus serotina	98-168	2-3									
Tsuga canadensis	23-14	35-22	21-13	5-3	8-5	6-4	2-1				
Prunus avium	96-55	2-1	2-1								
Fagus grandifolia	89-41	3-1		4-2			4-2				
Acer rubrum	63-26	29-12	9-3								
Liquidambar styraciflua	81-22	7-2	4-1		4-1	4-1					
Fraxinus americana	73-19	4-1	14-4	4-1	4-1						
Sassafras albidum	96-25	4-1									
Quercus borealis	52-12	13-3	17-4	5-1	8-2	5-1					
Cornus florida	44-7	56-9									
Acer saccharum	75-12	13-2	5-1	6-1							
Carya glabra	60-9	27-4	13-2								
Quercus velutina	41-7	29-5	6-1	6-1				6-1	12-2		
Ulmus americana	60-6	20-2	20-2								
Betula lenta	33-2		17-1	33-2		17-1					
Quercus alba	60-3			2-40							
Carpinus caroliniana	50-2	50-2									
Liriodendron tulipifera				17-1	17-1	34-2				17-1	17-1
Ostrya virginiana	33-1	67-2									
Quercus palustris		50-1	50-1								
Morus alba	100-1										
Crataegus sp.	100-1										
Magnolia virginiana		100-1									
Lindera benzoin	100-696										
Viburnum dentatum	100-192										
Viburnum acerifolium	100-64										
Phellodendron amurense	81-25	19-7									
Aralia spinosa	100-34										
Ailanthus altissima	100-28										
Malus sp.	100-17										

Table 6. Classification by seral class of all species sampled in the forest of the New York Botanical Garden, Bronx, New York.

Pioneer	Transition	Late Succession
Sassafras albidum	*Prunus serotina*	*Liriodendron tulipifera*
Prunus serotina	*Tsuga canadensis*	*Tsuga canadensis*
Viburnum acerifolium	*Prunus avium*	*Quercus velutina*
Aralia spinosa	*Fagus grandifolia*	*Liquidambar styraciflua*
Ailanthus altissima	*Acer rubrum*	*Quercus borealis*
Malus sp.*	*Fraxinus americana*	*Fagus grandifolia*
	Quercus borealis	
	Cornus florida	
	Acer saccharum	
	Carya glabra	
	Ulmus americana	
	Betula lenta	
	Quercus alba	
	Carpinus caroliniana	
	Ostrya virginiana	
	Quercus palustris	
	Morus alba	
	Crataegus sp.	
	Magnolia virginiana	
	Lindera benzoin	
	Viburnum dentatum	
	Phellodendron amurense	

* - planted

Table 7. Summary statistics for 3 soil parameters derived from the forest of the New York Botanical Garden, Bronx, New York.

	Sample Size	Mean (cm)	Range	Standard Deviation	Confidence Interval about mean (p=.05)	Coefficient of Variation
Leaf litter depth	151	1.93	0-6.50	1.34	0-4.61	69.4
Soil organic matter	139	30.66	7.14-77.69	13.64	3.38-57.94	44.5
Soil pH	147	4.11	3.61-6.96	.44	3.23-4.99	10.7