INDICATORS OF URBAN FOREST CONDITION IN NEW ORLEANS

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Abstract. Urban trees constitute a valuable environmental resource in many cities. Designing a tree maintenance and management strategy depends upon an understanding of the environments of urban trees and stresses on tree health and condition. Using New Orleans, Louisiana as an example, environmental indicators of tree condition are identified using data from sample inventory of trees. Tree condition is related to the types of land covers in the zone of root growth under the tree canopy, the presence of wires in the tree canopy and associated land uses. The inventory also shows that the New Orleans urban forest is a mature forest, which suggests special care is needed in order to protect and replenish the resource. this information can be used to plan urban forestry management strategies in New Orleans.

Résumé. Les arbres urbains constituent une ressource environnementale de grande valeur dans plusieurs municipalités. L'élaboration d'un programme d'entretien et de gestion des arbres est basé sur bonne compréhension de l'environnement physique des arbres et des stress subis par ces derniers. En Nouvelle-Orleans et en Louisiane, des indicateurs environnementaux sur la condition de santé des arbres furent identifiés en se servant des données d'inventaire des arbres obtenues par échantillon. La condition des arbres fut évaluée en fonction des aménagements au sol dans la zone de croissance des racines sous la cime de l'arbre, de la présence de fils dans la cime de l'arbre et des utilisations du territoire avoisinant. L'inventaire des arbres a aussi permis de constater que la forêt urbaine de la Nouvelle-Orléans est à maturité, ce qui suggère qu'un soin particulier est nécessaire afin de protéger et de renouveler cette ressource. Cette information peut être utilisée pour planifier les stratégies de gestion des arbres urbains en Nouvelle-Orléans.

Increasingly, forestry management principles are being applied in the urban context at the urging of the urban forestry profession, which has been active for about three decades (6). Urban foresters are promoting urban forestry as a field of research and as an activist movement in the urban arena. Research is focusing on describing the characteristics of urban forests and their ecosystems (7, 15, 19, 21, 22). Research is also identifying a variety of tangible benefits that urban trees provide to city dwellers. Urban trees improve air quality (28), ameliorate noise pollution (2), improve micro-climates (11), benefit water control and run-off (20), provide wildlife habitats (9), provide psychological benefits to people and enhance the quality of life (8), and increase land values (12).

In recognition of the functions of urban trees and the many interrelationships between trees and other aspects of the urban environment, the term "urban forest" is being increasingly applied to urban vegetation (1, 10, 23). The "urban forest" is defined as "Vegetation in urban areas acting in conjunction with other natural and cultural components of the consystem." (23).

The urban forest examined here is in New Orleans, Louisiana. New Orleans offers an opportunity to study an urban forest in a subtropical environment (26), unlike other urban forestry research, which has focused on cities in temperate zones (18, 19, 21, 22, 25). New Orleans is unusual because of its site. The city has been built on the natural levees of the Mississippi River, backswamps, marshes, and reclaimed land along Lake Pontchartrain (13). Little of the natural vegetative cover of the site remains; today's urban forest is anthropogenic.

Management of the Urban Forest Resource

Management of the urban forest resource requires intervention at three points: first, control over the location and selection of new trees added to the stock (inflow); secondly, maintenance of existing stock; and thirdly, control over trees removed from the stock (outflow). Stage one, tree planting, includes the selection of climatically appropriate species and the planting of trees where they will be able to thrive. This issue is well understood in New Orleans, where horticultural experts have publicized the issues of species selection and planting (14). An equally important aspect of tree planting is to locate trees in social contexts where they will receive some care, or, at least, not suffer exposure to vandalism. Sklar and Ames (26) have found that a tree planting program which specifically includes neighborhood groups and residents is most successful in Oakland,

California. New Orleans employs a similar strategy. Interested residents are sold low-cost trees and neighborhood requests for tree planting are honored, depending upon funding constraints. The third and final stage in the urban forest resource model, tree removal, is also well regulated in New Orleans by the Parkway and Parks Commission and a Tree Removal Appeals Board.

However, stage two, tree maintenance, is not well-implemented. Tree maintenance is not planned and it is under-funded in New Orleans. Ideally, a tree maintenance strategy can be based upon an inventory of every tree on city property, including information on species, size, condition, and immediate environment. Thus, trees in need of care can be identified and tree maintenance activities prioritized. Such an inventory is costly, however. In the absence of complete tree inventory information, maintenance strategy can be designed in conjunction with an understanding of the environmental indicators of tree condition. If, for example, the presence of wires in a tree is found to have a negative impact on tree health, then trees impacted by wires can be targeted for maintenance. Or, if trees located near industrial land uses are determined to be in generally poor condition compared to trees near other land uses, such trees can be targeted for special care. The purpose of this research is to identify the correlates of tree condition in New Orleans with objective of designing a tree maintenance strategy. Because urban forestry is a relatively new research discipline, the correlates of tree health in urban areas are not understood as well as the determinants of tree health in timber-producing forests.

While the condition and health of each individual tree depends upon species characteristics and tolerances, along with immediate environmental conditions, the object is to identify environmental correlates of tree condition in the aggregate. Just as a tree inventory provides information on tree size, the inventory also provides data on tree condition. As tree size data can be aggregated to give a picture of the biomass of the urban forest, tree condition can be aggregated to provide an understanding of the condition of the urban forest as a whole. Thus, tree condition in the aggregate refers to a classification of tree health for the population of trees. All urban trees are exposed to a particular set of environmental conditions which impact their health and condition.

Tree Condition and Urban Environmental Stressors

Trees in New Orleans are subject to a number of environmental stresses, which should be considered in any tree management plan. For example, air pollution has a negative impact on tree health (5). Telephone and power wires often require tree pruning, which can weaken trees and provide opportunities for invasion by disease-causing organisms (17). Also, soil compaction interferes with the tree's access to water and nutrients (31). Soil compaction can result from construction, paving root zones, traffic, or subsidence, a severe problem in New Orleans. Street trees in New Orleans are particularly susceptible to compaction because trees requiring greater than average growing-space tend to be located in restricted areas. Live oaks, which require substantial space for root growth, are often found on park strips along streets. Roots growing above ground are impacted by heavy pedestrian use or other damage. Vandalism also causes damage to trees in urban areas (27).

Planting tree species not suited to the New Orleans climate is another problem. The growing season is about 310 days in New Orleans (4). A winter freeze is not an unusual event. Residents of the city, however, have exhibited strong preferences for tropical vegetation over the years. Many species may not be well-suited to New Orleans. Experts agree that various species of palms, golden raintree and hackberry risk damage as a result of freezing temperatures (14). While microclimates protect some trees, freezes periodically kill many tropical plants. Freezing temperatures during the winter of 1983-84 caused the death of 1,111 trees and 1,623 shrubs on city-owned property (16). Horticultural experts in New Orleans are currently educating the public on selection of appropriate species, but some trees which are not freeze-tolerant still survive.

Research Methods and Data Collection

Tree inventory methods usually require the

identification of tree species, location of trees, crown dimensions, health, local environmental influences on trees and potential stocking levels of trees throughout an area (10). While some inventories focus on street trees measured in vivo (18), others use aerial photos (22, 24). A field inventory, however, facilitates the collection of detailed information on ground cover beneath the canopy, the presence of wires, and other types of environmental information that cannot be accurately determined from air photos. In the New Orleans project a field inventory is used.

Data collection proceeded as follows. Field data were collected on 310 randomly selected block-faces (or block perimeter along one street) in the urbanized areas of Orleans Parish, the county in which the City of New Orleans is located. In total, approximately one percent of the block-faces in the city were sampled. Computer generated lists of random numbers were used to provide x and y coordinates on a 1:24,000 map of the city. The block-face nearest the generated coordinates was selected for sampling. When necessary, a toss of a coin selected the side of the street. The sample included trees located on the parkstrip between the sidewalk and street, or "street trees," trees in front yards within 20 feet of the sidewalk and, in cases of a median strip in the street, trees on the sampling side of the median strip from a line in the center of the median strip. If trees were located in the center of the median strip, every second tree was included in the sample. The transect length was generally 300 feet, the average length of a city block in New Orleans, but ranged from 32 feet to 1,633 feet. A total of 1388 trees were included in the inventory with 823 located on the parkstrips, 99 in a median strip, 461 on private land within 20 feet of a street, and 5 on parkland or open space within 20 feet of the street.

All tree data were collected in the field by student workers trained by U.S. Forest Service personnel. Tree height was measured using a clinometer and measuring tapes were used to obtain crown dimensions and trunk diameter at breast height (dbh). Data were also collected on aspects of the trees environment and potential stressors, including the presence of transmission wires, degree of pruning, tree location with respect to the street, associated land uses, and the area under tree canopy covered by soil and grass or impervious surfaces (such as streets, sidewalks, and buildings). While roots often extend beyond the perimeter of the tree canopy, the area under the canopy reflects a reasonable estimate of the root growth zone. Each tree was classified according to general condition and health. The determination of tree condition is commonly made by observing tree foliage, branches, trunk, roots, and soil (3). The condition of each tree surveyed was classified according to visible characteristics, such as crown development; foliage density, size and color; the presence of insects and disease; trunk condition and damage; exposure or injury of roots; the dropping of twigs and the presence of dead wood. Also, the presence of significant new growth was another dimension of tree condition.

Each tree is assigned to one of five condition categories: vigorous, good; vigorous, poor; stable, good; stable, poor; and declining, dead. "Vigorous" or "stable," the first dimension, refers to whether a tree evidenced recent growth as indicated by twigs and branches; "good" or "poor," the second dimension, refers to general tree health. The modal value (N=747) for all trees in New Orleans is "stable, good," indicating a tree in basically healthy condition, but exhibiting little or no recent growth. The second largest number of trees (N=475) can be classified as "Vigorous, good," or trees in excellent health with significant recent growth. Smaller numbers of trees are classified as "Stable, poor" (N=88) and "Vigorous, poor" (N=25). "Stable, poor" describes trees exhibiting no recent growth and in poor condition with respect to foliage, trunk or root development, or insect damage. "Vigorous, poor" is a category which describes a tree in poor condition, but a tree with recent growth. Perhaps this accounts for the small number of trees in that category. Only 53 trees in the sample, or 3.8 percent, are classified as declining or dead. Tree age is one variable that was unavailable because collection of tree age data requires core samples of tree growth rings.

Characteristics of Trees Found Within the Urban Forest

Compilation and analysis of the field data revealed 93 species of trees in the New Orleans sample, both native species and exotics. Five tree species each account for more than 5 percent of all trees: live oak, crape myrtle, loblolly pine, slash pine, and southern magnolia. These are the dominant species in the New Orleans urban forest.

Tree sizes range from small newly-planted trees to aging giants. The largest tree sampled is 53 inches dbh, but some old live oaks not included in the sample are even larger. The mean dbh of all trees is 13.49 inches. The mean height of all trees is 34 feet. The mean crown dimensions are 24.3 feet parallel to the street and 24.3 feet perpendicular to the street. The range of crown size diameters is 3 feet to 151 feet. Some tree crowns, especially those of mature live oak, extend over the street and beyond. Overall, the data on dbh, total height and crown describe a mature urban forest. Since many trees are mature, tree maintenance is essential to the preservation of the resource.

An examination of tree condition for each tree species reveals wide variability. Discounting species with fewer that 10 trees in the sample, species can be classified into 3 groups according to the percentage of the species in the modal tree condition category (Table 1). The first and largest group, Type 1, includes species having the largest number of trees in the "Stable, good" category. These Type 1 species include crape myrtle, southern magnolia, live oak, loblolly pine, and slash pine. These species are also the dominant species and among the largest species by size in the New Orleans urban forest. Other Type 1 species include cherry laurel, bald cypress, American elm, hornbeam, silver maple, sugar maple, mimosa, laurel oak, pecan, sweetgum and sycamore. These species are mature and will require great care in order to preserve the stock of trees. With age an increasing portion of the stock will be subject to the stresses connected with an urban environment.

A second group of species, Type II, have their largest number of trees represented in the "Vigorous, good" category (Table 1). These species, which include small leaf elm, red maple, and water oak, are probably species that have been planted in the recent past as indicated by

their size. Species in this group will require no special care as a group in the near future.

A third group of species, Type III, includes species which exhibit modal values in the "stable, poor" or "declining, dead" categories (Table 1). The golden raintree and hackberry (sugar-berry) are species which are currently in very poor condition. Replacement of these trees will need to be planned and implemented.

Identifying Indicators of Tree Condition

Since the sample inventory includes variables measuring each tree's immediate environment, the next step is to test statistically the environmental variables for their relationship to tree condition. Where a statistical relationship is found

Table 1. Trees classified by condition for species with ten or more trees included in the sample.

Species	Vigorous, good	Vigorous, poor	Stable, good	Stable, poor	Declining or dead
Type 1					
American Elm	5	1	18	0	1
Bald Cypress	4	1	7	0	0
Cherry Laurel	0	2	9	0	0
Crape Myrtle	86	5	161	9	3
Hornbeam	2	0	15	0	0
Laurel Oak	16	0	34	2	0
Live Oak	133	4	177	1	0
Loblolly Pine	27	1	60	4	0
Mimosa	1	2	7	0	1
Pecan	5	0	15	0	1
Slash Pine	40	0	54	0	0
Southern Magnolia	19	1	52	1	
Sweetgum	3	0	8	5	0
Sycamore	2	1	14	0	0
Type II					
Eastern Cottonwood	14	1	4	11	2
Red Maple	16	0	2	0	0
Small Leaf Elm	23	0	19	0	1
Water Oak	30	2	13	0	0
Type III					
Golden Rain Tree	0	0	3	23	28
Hackberry (Sugarberry)	3	0	5	22	7

the variable qualifies as an indicator of tree condition. Such an indicator is not necessarily a cause of poor tree health. For example, wires in a tree's canopy are not necessarily a cause of tree decline, but rather an indicator of potentially damaging tree pruning and possibly retarded vigor and disease.

The first hypothesis examined involves the land cover in the zone of root growth. It is hypothesized that trees in the categories indicating good condition will tend to have a greater percentage of the area below their canopy covered by soil and grass, allowing for soil aeration, movement of water and root growth relatively unhampered by obstructions such as curbs, sidewalks and buildings. Alternatively, it is hypothesized that trees in moderate or poor condition will tend to have a higher percentage of the area under the canopy covered by impervious surfaces, resulting in difficult growing conditions.

Hypothesized relationships between tree condition and environmental indicators are tested using an analysis of variance (F ratio). If the analysis of variance indicates a relationship, a posteriori t-tests are used to indicate significant differences between trees in the vigorous categories ("vigorous, good" and "vigorous, poor") contrasted with trees in the less-healthy, stable categories ("stable, good" and "stable, poor") (29, 30). If the F ratio is not significant, there is no relationship between the tree health and the environmental indicator.

First, the potential relationship between tree condition and soil and grass cover under tree canopy is examined using an analysis of variance (Table 2). Because the analysis of variance indicates at least one significant difference between condition categories (F=31.95, p < .0001), a posteriori contrasts are used. Trees judged to be in the two vigorous categories exhibit a higher proportion of the area under their crowns covered with soil and grass than trees in the two stable categories. A posteriori contrasts point to a statistical relationship (t=2.76, p=.006). Similarly, the relationship between tree health and the proportion of the area under tree canopy covered by impervious surfaces is supported by the data (Table 3). Vigorous trees exhibit a lower proportion of the area under their canopy covered by im-

pervious surfaces than less-healthy, stable trees (t=-9.10, p=.002).

Another very immediate environmental impact experienced by trees is the presence of overhead wires. Often tree pruning or branch removal is required. Hence, it is hypothesized that trees experiencing no impact from wires will be healthier that trees that are impacted by wires. For purposes of analysis, wires are either present, meaning that wires extend through the tree crown, or wires are absent. Since both variables are categoric, a Chi-square statistic is computed. Analysis reveals a significant relationship between tree condition and the presence of wires (Table 4)., Trees without wires are almost as likely to be

Table 2. Tree condition and the percentage of the area under tree canopy which consists of soil and ground cover.

Condition	Mean percent*	Standard deviation	Number of trees
Vigorous, good	70.4	25.9	475
Vigorous, poor	60.4	32.1	25
Stable, good	55.6	25.6	747
Stable, poor	58.5	27.6	88
F ratio = 31.95, significance P = .0001			

*Percent area under the tree canopy which consists of soil and ground cover
Note: Data not collected for trees categorized as "dead or declining."

Table 3. Tree condition and the percentage of the area under tree canopy which consists of impervious surfaces.

Condition	Mean percent*	Standard deviation	Number
Vigorous, good	28.7	28.7	475
Vigorous, poor	32.0	29.1	25
Stable, good	41.3	26.0	747
Stable, poor	39.1	27.6	88
F ratio = 21.27, Significance P = .001			

*Percent area under tree canopy which consists of impervious surfaces
Note: Data not collected for trees categorized as dead or declining.

classified as "vigorous, good" (47.6%) and "stable, good" (45.6%). However, trees that are impacted by wires are much more likely to be classified as "stable, good" (72.8%) than "vigorous, good" (15.9%). Thus, the proportion of trees in the less-healthy stable categories is greater when wires are present than when wires are absent. Therefore, wires and tree pruning to accommodate wires are detrimental to tree health.

Another environmental hypothesis involves land use. It is suspected that tree condition will vary by a tree's location with respect to categories of land use, which may be indicative of certain stressors such as air pollution near particular land uses, pedestrian and vehicular traffic associated with certain land uses, differential care and vandalism, or crowding by buildings. Land use categories include: 1) single-unit residential, 2) multiple-unit residential, 3) industrial, 4) institutional, 5) commercial, 6) parks, and 7) vacant or open space. It is hypothesized that residential trees are healthier than commercial, industrial, or institutionally-located trees because they will receive more care and are typically located along lower density traffic corridors (both vehicular traffic and foot traffic).

The Chi-square test indicates a complex relationship between tree condition and land uses (Table 5). Trees located on or near single-unit residential property are less likely to be in good condition than trees located in association with

multiple-unit residential property, an unexpected finding. The condition of trees located in or near commercial land uses, parks and vacant or open-space range from vigorous to stable, with approximately equal chance of being in either category. Trees located on or near industrial and institutional land uses are very likely to be in stable rather than vigorous condition.

A final potential relationship which can be tested using the inventory data is whether public trees are in better condition than private trees. Inventoried trees include trees located on public land which are the responsibility of the city, as well as trees which are located on private land. For analysis purposes trees in median strips, park strips and park and open space are aggregated as "publicly-managed trees" and compared to "privately-managed trees." No dramatic dif-

Table 4. Tree condition and the presence of wires

| Condition | Wires absent | | Wires present | |
	Number	%	Number	%
Vigorous, good	394	47.6	81	15.9
Vigorous, poor	17	2.1	8	1.6
Stable, good	377	45.6	370	72.8
Stable, poor	39	4.7	49	9.6

Chi-square = 142.6, df. = 3, significance P = .0001

Note: Trees classified as "dead, declining" not included in analysis.

Table 5. Tree condition and land uses.

| | Number (and percent) of trees in land use categories | | | | | | |
Condition	Single residential	Multiple residential	Industrial	Institutional	Commercial	Parks	Vacant/open spaces
Vigorous (good and poor)	377	64	3	3	30	11	12
	(35.8)	(64.6)	(15.0)	(7.0)	(49.2)	(40.7)	(41.4)
Stable (good and poor)	676	35	17	40	31	16	17
	(64.2)	(35.4)	(85.0)	(93.0)	(50.8)	(59.3)	(58.6)

Chi-square = 57.65, d.f. = 6, significance P = .0001

Note: "Vigorous, good" and "vigorous, poor" are combined and "Stable, good" and "Stable, poor" are combined in order to minimize the number of empty cells and cells with few cases.

ference in tree condition is apparent, although publicly-managed trees are somewhat more likely to be concentrated at the extremes of the continuum, either "vigorous, good" or "declining, dead" (Table 6). Privately-managed trees tend to be more concentrated in the moderately healthy category, "stable, good." Interpretation is difficult because residents often care for nearby public trees as Sklar and Ames (26) explain.

Conclusions

Assuming that a uniformly healthy tree population is a goal of urban forestry, the analysis of the New Orleans tree inventory data has uncovered a number of relationships between tree condition and environmental indicators that can be useful in designing and implementing a tree maintenance program. Emphasis is on using indicators of tree health which point to the need for enhanced maintenance or less maintenance depending upon a tree's exposure to environmental stressors. Secondly, a maintenance program should rely on indicators that are easily observable in a sample tree inventory or available from other data sources, such as maps or municipal data bases. The sample inventory procedure explained here or existing data bases are less costly than implementing a comprehensive tree inventory.

Research results indicate that more care in the location of trees and tree pruning is needed because of the strong relationship between wires and poor tree condition. Wires are easily observ-

ed and data on the location of wires can be supplied by public utilities, facilitating the efficient deployment of tree maintenance work crews. Trees located on or near industrial and institutional land are severely impacted, followed by trees near single-unit residential property. Trees located near commercial land, parks, vacant land or open space and multiple-unit residential land are moderately impacted. While land use, considered alone, is not a cause of tree condition it may be related to growing space or other environmental conditions or differential management practices. Land use maps and other data are readily available and can be supplied to urban forestry departments by city planning agencies. The proportion of the land under the tree canopy which is covered by impervious surfaces and soil and ground cover is also related to tree condition. Impervious surfaces impact tree health negatively, while soil and ground covers provide a more beneficial environment for tree growth. This suggests that street trees located in areas with narrow park strips, which are easily catalogued and mapped, should be targeted for special care.

Many of the findings of the study on the urban forest of New Orleans are expected, others are unexpected or counter-intuitive. Since the New Orleans urban forest is a mature forest with a very diverse mix of tree species, the findings should not be generalized to other cities in the absence of a similar study or a complete tree inventory. Research indicates that urban forest structure differs by city (21,25). Probably, the bioclimatic zone in which cities are located, their land use patterns, and their histories of development determine urban forest variability between cities. Further research will answer this question and help urban foresters understand which management practices can be successfully transferred to other cities.

Table 6. Tree condition among privately-managed and publicly-managed trees.

Management responsibility

Tree condition	Privately-managed trees		Publicly-managed trees	
	Number	%	Number	%
Vigorous, good	134	29.1	340	36.9
Vigorous, poor	11	2.4	14	1.5
Stable, good	279	60.5	466	50.5
Stable, poor	26	5.6	61	6.6
Declining/dead	11	2.4	41	4.4

Chi-square = 16.36, df = 4, significance P = .0026

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