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Applications of Urban Tree Canopy Assessment and Prioritization Tools: Supporting Collaborative Decision Making to Achieve Urban Sustainability Goals

Urban Tree Canopy (UTC) Prioritizations can be both a set of geographic analysis tools and a planning process for collaborative decision-making. In this paper, we describe how UTC Prioritizations can be used as a planning process to provide decision support to multiple government agencies, civic groups and private businesses to aid in reaching a canopy target. Linkages to broader City-scale sustainability plans are explored. This article represents an extension and update to the UTC Canopy Goal Setting Guide by Raciti et al (2006). We conclude with recommendations for a market-like analysis of neighborhoods to better match planting initiatives to particular neighborhoods' motivations, capacities and interests in order to improve the adoption of improved urban forestry practices.

Keywords
Urban Forestry, UTC, urban tree canopy, geographic information systems, GIS, trees, planning, sustainability

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INTRODUCTION

The purpose of this article is to describe how diverse stakeholders can use urban tree canopy (UTC) Assessment and Prioritization tools to collaboratively achieve urban sustainability goals. The motivations for this article are practical, methodological, and theoretical. From a practical perspective, there is a growing need for diverse stakeholders to work collaboratively on interrelated strategies to achieve comprehensive, urban sustainability goals. Methodologically, these same stakeholders need tools that integrate social, economic, and ecological data. These tools need to be relevant to stakeholders' management goals, transparent, time efficient, and interoperable with their data systems. Theoretically, the application of these tools creates new research questions for the scientific community to address. We use our experience working in Baltimore, Maryland to describe this process in order to share the methods we have developed and the lessons we have learned.

There is an emerging shift in urban land management practice from a focus primarily on street trees and parks to an "All Lands, All People" approach (Grove 2009). This "All Lands, All People" approach is an inclusive framework based on all urban land use types; multi-sector coordination and collaboration; and integration of social and ecological knowledge and goals. In order to operationalize this approach, it is necessary to characterize land cover at the unit of individual property parcels, and integrate social and ecological data corresponding to diverse sustainability goals so that all neighborhoods and parcels can be prioritized for tree planting (Grove, 2009; Locke et al., 2010).

Urban Tree Canopy (UTC) tools provide a set of methods to operationalize the "All Lands, All People" approach. Currently there are two types of UTC methods. UTC Assessment tools are used to assess existing and possible UTC at any spatial scale from the property parcel level to a regional extent. The second set of tools are the UTC Prioritization protocols which are used to identify where to increase UTC at watershed, neighborhood, and parcel levels based upon diverse stakeholders' goals and preferences among goals. These goals may be ecological, social, or economic in nature – or a mix of the three.

Significant progress can be seen in the development and application of UTC tools with our team completing 68 UTC Assessments since 2006[1,2]. These assessments cover 8,780 sq. miles, 837 communities, include over 28,000,000 people, and range in geographic size from smaller urban areas like Scranton and Lancaster, PA, to counties such as Jefferson WV, and Montgomery, MD. A sample of UTC reports can be found here: http://www.nrs.fs.fed.us/urban/utc/pubs/ and http://letters-sal.blogspot.com/2011/04/tree-canopy-assessment-reports.html. This achievement suggests both demand for UTC analyses and the ability of UTC teams to develop cost-effective approaches for analyzing large amounts of data and produce operational information to decision makers in a timely manner.[3] In the case of New

[1] The UTC Team members are included in Appendix 1: List of Organizations who attended UTC Prioritization Workshop

[2] Note that other institutions create land cover maps and UTC Assessments. Examples of these organizations include Virginia Tech (McGee et al. 2012), the Davey Resources Group, Plan-It Geo, and AMEC.

[3] See MacFadden and others (2012) and O'Neil-Dunne and others (2012) for an explanation of how the requisite high-resolution land cover maps are created using object based image analysis. To provide context for these assessments, the USGS National Land Cover Database (NLCD) contains ~13 billion 30 meter pixels for the Continental United States, while the sum of our UTC assessment land cover maps is in excess of 300 billion pixels.

York City, the Department of Parks and Recreation used its UTC Assessment and Prioritization analysis to set a goal and prioritize its $400 million tree program, the Million Trees NYC initiative, over a ten year period[4].

METHOD

The case study we describe here for Baltimore uses UTC Prioritization tools described by Locke and others (2010). Baltimore may be similar to many other cities in the United States in that there is a large and diverse number of "tree" stakeholders from public, NGO, neighborhood, and private sectors. In Baltimore, we identified 25 stakeholder organizations from these sectors. There is insufficient space on public lands to achieve the City's UTC Goal of 40% of city land area. High resolution estimates of tree canopy revealed that if every opportunity for street tree's canopy to grow in the right of way were realized, and if all parks reached 100% tree canopy, the city will would achieve only ~10% of its total 40% canopy goal. The reaming 30% of the tree canopy goal have to be established on other lands in the City (Galvin et al., 2006; O'Neil-Dunne, 2009). Completely canopied parkland may not be desirable, either. An "All Lands, All People" approach that includes public, private, community, and abandoned lands is needed. Independent action is inadequate: no agency, organization, single landowner or business has sufficient funds or land to achieve a city's UTC goal. Coordination and collaboration are needed and depend upon identifying common or complementary interests, categories of programs, or areas for action.

Based on these needs the UTC Prioritization framework was built. Given the known and studied benefits of trees as described by Locke and others (2010) and catalogued in depth elsewhere [5,6] spatial data are gathered to identify where those benefits of trees are lacking. Next organizations whose mission or mandate aligns with that particular benefit, function, or property of trees are identified. For example, reducing impervious surfaces and planting trees to intercept, filter, slow, and uptake storm water may reduce infrastructure costs associated with treatment while reducing surface water pollution (Beattie et al. 2000; Nowak et al. 2007). Therefore, an NGO interested in water quality, or a government agency charged with meeting water quality standards may consider using trees as part of an overall water quality strategy. Data on impervious surfaces, citizen reported floods, and/or proximity to surface waterways could be used to identify where to plant trees for the specific water quality management objectives. UTC Prioritization works by matching known benefits of trees, to places lacking those benefits, and then matches those locations to organizations positioned to manage those issues that trees help ameliorate.

We began our work in Baltimore in partnership with the City's TreeBaltimore Program, which is part of the Division of Forestry in the Department of Recreation & Parks. We had developed the methods and piloted the first UTC assessment in 2006 using Baltimore as our case study (Galvin et al., 2006; Raciti et al., 2006) and later refined our land cover mapping techniques (O'Neil-Dunne, 2009). Subsequently, the City established a UTC goal of increasing

[4] http://www.milliontreesnyc.org/html/newsroom/pr_milliontreesnyc_launch.shtml

[5] (2012). Benefits of Trees and Urban Forests - Alliance for Community Trees. Retrieved June 17, 2013, from http://www.actrees.org/files/Research/benefits_of_trees.pdf.

[6] (2011). Urban Forestry Bibliography Created by the ... - MillionTreesNYC. Retrieved June 17, 2013, from http://www.milliontreesnyc.org/downloads/pdf/urban_tree_bib.pdf.

the City's tree canopy to 40% in 30 years[7]. This goal was set by staff in the Department of Recreation and Park's Forestry Division and the Director of Recreation and Parks made a recommendation to the Mayor. Staff from the Parks & People Foundation and Blue Water Baltimore participated in the evaluation of the UTC Assessment data and agreed to the goal. All three subsequent Mayors have also endorsed the goal. Staff from the USDA Forest Service and the Maryland Department of Natural Resources provided the technical support, data analysis, and the report. As the Division of Forestry worked to achieve the City's UTC goal, it became obvious to Forestry staff that they had insufficient resources to achieve the City's UTC Goal through a combination of planting, canopy maintenance and loss reduction efforts. TreeBaltimore staff began to search for additional partnerships and resources to leverage. While the initial premise was that the Forestry Division would work with non-profit and private partnerships to achieve the City's goal, it was increasingly clear through informal conversations that other city agencies had regulatory requirements or programmatic interests that involved tree planting.

Common interests and little coordination or sharing of resources among City agencies' and local NGOs highlighted the high degree of fragmentation in the activities used to achieve the City's urban tree canopy goal. These conditions are not new to resource management, and have been described by Yaffee's (1997) as "recurring nightmares:"

(1) a process in which short-term interests out-compete long-term visions and concerns;
(2) conditions in which competition supplants cooperation because of the conflicts that emerge in management issues;
(3) the fragmentation of interest and values;
(4) the fragmentation of responsibilities and authorities (sometimes called "functional silos" or "stove pipes"); and
(5) the fragmentation of information and knowledge, which leads to inferior solutions.

To address these "recurring nightmares," we worked with Division of Forestry staff to develop a two phase processes for stakeholder involvement to prioritize planting. In the first phase we met with staff from different city agencies on an individual basis to explain prioritization and elicit feedback on criteria. In the second phase we met with stakeholder organizations from public, non-profit, community, and private sectors in a workshop setting to provide specific input for prioritization in the form of votes. All of these stakeholder organizations had expressed interest previously in tree issues in the City. Ultimately, the goal of this process was to develop interest and support from other city agencies to increase tree canopy and to involve public, NGO, and private stakeholders to identify tree canopy priorities to promoting biodiversity.

Phase I: Public Agencies

Working with TreeBaltimore staff, we identified and interviewed key representatives from five other City agencies that had an interest in tree canopy. These agencies included the Departments of Planning, Housing & Community Development, Transportation, Public Works, Public Health, and Education. We met individually with each agency. First, we described the UTC Assessment and Prioritization tools using our Assessments in Baltimore and both Assessments and Prioritization for New York City so that they had a sense of data needs, analytical capabilities, and possible products. After our presentation, we discussed their agency's regulatory

[7] http://articles.baltimoresun.com/2006-03-30/news/0603300035_1_tree-canopy-forestry-feldberg

requirements and programmatic interests in tree canopy and which variables they would use, if they had a prioritization tool, to prioritize where to plant trees to meet their requirements or interests. We revised our presentation to incorporate each agency's suggestions for prioritization criteria and variables to use, (Table 1). Then we asked them if they would provide the data they identified. Each meeting took approximately two hours. GIS staff from each agency provided the data they had listed so they could be incorporated in to subsequent prioritizations for their organization or others.

The interests among public agencies were varied. For instance, the Departments of Transportation and Public Works sought to reduce the amount of impervious surfaces in the City. Housing and Community Development considered greening to be a strategy for community stabilization and re-development. Public Health understood trees to be important for reducing cases of heat-related stress and asthma. Education sought to create greener and more attractive school campuses, while Planning considered trees to be important to a variety of sustainability goals from reducing energy consumption to improving water quality and reducing the severity of flood events.

Phase II: NGOs, Community Groups, Private Businesses

In Phase II we worked with NGOs, community groups, businesses, and government agencies. We repeated the process from Phase 1 with several modifications. We made our presentation in a large group setting to representatives of 25 organizations (Appendix 1), we conducted a paper survey (Appendix 2) using a refined version of Table 1 (Appendix 2, Question 2), and the entire meeting lasted 2 hours.

The survey had three parts. First, participants were presented with more than two dozen criteria variables for prioritizing tree planting and asked to allot ten votes among the variables representing their preferences. This voting approach assumed that people voted in ways that are reflective of their organization's management objectives. Variables could be voted for multiple times. Variables are indicators of where the benefits of trees are lacking. Trees and access to open space (frequently tree dominated landscapes) are commonly associated with improved health outcomes (Bell et al. 2008; Jackson, 2003; Lovasi et al. 2008; Mitchell and Popham, 2008; Takano et al. 2002), therefore planting in areas with poor public health may be desirable. A "write-in" option was also provided, but not all write-in options could be accommodated because the associated data did not exist or were not otherwise available. Based upon "write-in" requests, two additional variables were subsequently added: the percent of each block group's area that is a historic district and the percent of the block group area beneath the canopy of trees 50 feet or taller.

Table 1. Summary of Baltimore City public agencies' criteria and variables related to trees and their benefits, as well as the linkages to goals in the City's sustainability plan. City Agencies column: Agencies that self-identified with a major criteria, or were identified by another agency. Sustainability Plan column: linkages of increasing tree canopy to other goals, as shown in Table 2.

Major Criteria	Criteria Variables	City Agencies	Sustainability Plan
Public Health & Safety	Life expectancy; rates including mortality, mortality from heart disease; mortality from strokes, mortality from respiratory disease, mortality from diabetes, infant mortality rate	Health, Planning	Pollution Prevention Goals 2, 4 & 5
	Asthma by zip code	Health, Planning	Pollution Prevention Goals 2, 4 & 5
	Dependency Ratio	Health, Planning	
	Urban Heat Island: surface temperature and solar exposure	Health, Recreation and Parks, Planning, Transportation	Pollution Prevention Goal 2
	Crime: Personal, Property and Total	Police	
	Transportation Connections	Health, Planning, Transportation, Education	Transportation Goals 1, 2, 3 and 4
Environmental Justice	Toxic Releases Inventory	Health, Planning	Pollution Prevention Goals 2 & 4
	Brownfields	Planning, Public Works	Cleanliness 3, Pollution Prevention Goal 4
	Poverty	Planning	
	Race	Planning	
	Home ownership	Planning	
	Percent Parks	Recreation and Parks	Greening Goal 3
Water Quality	Percent Impervious Surface	Public Works, Transportation, Planning	Pollution Prevention Goal 3
	Watershed H20 quality assessments	Public Works	Pollution Prevention Goal 3
	Stream corridors	Public Works, Recreation and Parks	Greening Goal 4
	Flood Plains	Public Works, Recreation and Parks, Planning	
	Critical Area	Recreation and Parks, Planning	Greening Goal 4
	Greenstreets	Public Works, Transportation, Recreation and Parks, Planning	Cleanliness Goal 1, Pollution Prevention Goal 3, Greening Goal 1
	Blue alleys	Public Works, Transportation, Recreation and Parks, Planning	Cleanliness Goal 1, Pollution Prevention Goal 3, Greening Goal 1
	Flooding	Public Works, Planning	
Air Quality & Noise Pollution	(Major) Road Density	Transportation	Pollution Prevention Goal 2
Critical Places	Schools, hospitals, libraries, recreation centers, and elderly care facilities	General Services, Recreation and Parks, Planning, Housing and Community Development, Education	Education & Awareness Goals 1, 2, 3 &4
	Population density (per square mile)	Planning, Public Works	
Community Presence	Potential stewardship	Recreation and Parks, Planning, Housing and Community Development	Education & Awareness Goals 2, 3 & 4

Table 2. Key to Sustainability Goals listed in Table 1.

Sustainability Plan Key:	
Cleanliness Goal 1	Eliminate litter throughout the City
Cleanliness Goal 3	Transform vacant lots from liabilities to assets that provide social and economic benefits
Education & Awareness Goal 1	Turn every school in Baltimore City into a green school
Education & Awareness Goal 2	Ensure that all city youth have access to environmental stewardship programs and information
Education & Awareness Goal 3	Raise the environmental awareness of the Baltimore community
Education & Awareness Goal 4	Expand access to information on sustainability
Greening Goal 1	Double Baltimore's Tree Canopy by 2037
Greening Goal 3	Provide safe, well-maintained public recreational space within ¼ mile of all residents
Greening Goal 4	Protect Baltimore's ecology and biodiversity
Pollution Prevention Goal 2	Improve Baltimore's air quality and eliminate Code Red days
Pollution Prevention Goal 3	Ensure that Baltimore water bodies are fishable and swimmable
Pollution Prevention Goal 4	Reduce risks from hazardous materials
Pollution Prevention Goal 5	Improve the health of indoor environments
Transportation Goal 1	Improve public transit services
Transportation Goal 2	Make Baltimore bicycle and pedestrian friendly
Transportation Goal 3	Facilitate shared-vehicle usage
Transportation Goal 4	Measure and improve the equity of transportation
Source: Baltimore Sustainability Plan http://www.baltimoresustainability.org/sites/baltimoresustainability.org/files/Baltimore%20Sustainability%20Plan%20FINAL.pdf	

Most criteria were included because of the known benefits of urban trees. For example, heat may be lethal in the summer months in urban areas (Son et al. 2012). Trees reduce temperatures by intercepting the sun's rays and casting shadows, the evapotranspiration process cools air, and planting may be accompanied by a reduction in impervious surfaces which store and emit heat (Akbari et al. 2001; Akbari and Konopacki 2005; Nowak, 2002; Nowak et al. 2007; Rosenfeld et al. 1998; Streiling and Matzarakis 2003). Therefore trees may help prevent heat-induced injuries and mortality. High surface temperatures and percentages of impervious surface can be combined with measures of population vulnerability (dependency ratio) to identify places to plant trees for improved health outcomes.

A couple of criteria were identified by participants for practical motivations unrelated to the City's sustainability plan. First, historic landmarks or districts may have maintenance budgets that can be used for beautifying a site with trees and retaining the "historic" appearance of an area. Second, neighborhoods with existing canopies of "big trees" may be concerned that these trees will be lost because of their height and susceptibility to windstorms, or because they fear the trees are getting old and are at risk to disease or senescence. Thus, neighborhoods with big trees may want to plant the next generation of trees to ensure a sustained succession of canopy over the long.

A second part of the survey asked participants about the types of sites where they work, or Categories of Interest (termed "COI"). The suggested categories were based upon A Typology of Forestry in an Urban Ecosystem, first described by Grove and others (2005) and later refined

by Raciti and others (2006). Categories of Interest include street trees, abandoned lots, private residential lands, parks, schools, stream valleys-riparian areas, shoreline areas or other.

In the third part, representatives of participating organizations were also asked, "Where do you work" and asked to choose from four Areas of Interest (termed "AOI's"). Answer choices were Neighborhood, Watershed, Council Districts, City or Other. When taken together, combinations of COI's and AOI's may form the basis for different strategies for reaching tree canopy goals. A future goal is to include a further developed typology that would enable improved targeting of neighborhoods based on a blend of site type characteristics to make outreach efforts more locally applicable. See Appendix 2 for the complete survey instrument. In return for completing the survey, we promised each organization that we would provide them with their own prioritization map based upon their prioritization votes as well as a summary map of all the organizations votes combined. We promised to provide these maps in both paper and digital formats (jpeg and pdf) within one month. Finally, we asked to schedule a meeting in one month so that we could present and discuss the results and decide on next steps.

After the survey response data were collected and tabulated, descriptive statistics were calculated to characterize the survey responses. Hierarchical cluster analyses were performed using the R Programming language (R Development Core Team 2012) on the prioritization criteria, COI and AOI votes. A Euclidean distance matrix was first defined for each set of questions, and then Ward's method of agglomeration (Ward 1963) applied using the `hclust()` function in the statistical package R (See Supplemental Material for the R scripts created for this paper). Used in this way, cluster analysis acts as an exploratory and visualization tool for identifying relative similarities simultaneously across both rows and columns (or organizations and their votes in this case).

FINDINGS

Using our interviews in Phase I and surveys in Phase II, we summarize our results by several dimensions of coordination and collaboration among stakeholders: 1) overlap among public agencies' programs; 2) stakeholder preferences for different UTC criteria; and 3) stakeholder programs by a) categories of interest and b) areas of interest.

1. Overlap among Public Agencies' Programs.

Significant opportunities exist for coordination and collaboration among government agencies in the City of Baltimore. Nine agencies were identified with programs that were directly or indirectly related to trees. Several agencies were named as having an interest even though they were not interviewed. The opportunities for coordination and collaboration were uncovered through these meetings, the workshop, and our surveys. The agencies included Department of General Services, Education and the Police Department. For the major prioritization criteria, there were mutual interests among public agencies for 5 of the 6 criteria, as indicated in Table 3 and the maps in Appendix 3 indicate. In several cases, the number of agencies with mutual interest for a Major Criteria ranged from 4 to 5 agencies. Some agencies were "landowners", such as Recreation and Parks, and Transportation. These lands were often physically adjoining, which represents opportunities for coordination and collaboration. In other cases, agencies were "landless" such as Planning, Public Works, and Health. This fact represents an opportunity for collaboration among "landless" agencies, technical assistance and resources to meet their

programmatic requirements, and landowner agencies who are in deep need for resources and additional expertise to better meet the City's diverse sustainability goals

Results from our interviews of public agencies show that increasing UTC was more than just a "greening" goal and was linked to many of the City's Sustainability goals, as shown in Table 2. While it might be expected that UTC was related to other Greening Goals, it was unexpectedly related to other Sustainability Goals that included Cleanliness, Education and Awareness, Pollution Prevention, and Transportation (Table 2, Appendix 3). Thus, tree planting had a multi-functional role that addressed numerous sustainability goals at the same time.

2. Stakeholder Preferences for Different UTC Criteria

Survey responses from our stakeholder interviews indicated a strong interest in diverse environmental, social, health, and cultural priorities. These included percent impervious surfaces (24.4%), potential stewardship (11.6%), urban heat island (10.0%), stream corridors (7.2%) and "critical places" - places such as schools, hospitals, and recreation centers (6.8%). Impervious surfaces was by far the most popular criteria variable, receiving 61 votes (24.4 %) which was more than double the second most popular criteria variable, potential stewardship, which gathered 29 votes (11.6%). The fact that the five most popular criteria include environmental, social, health, and cultural priorities suggests that these stakeholder groups are thinking holistically, more collectively and beyond professional "silos" (Table 4). The substantial support for reducing impervious surfaces and improving water quality is likely attributable, in part, to the cultural and historic significance the Chesapeake Bay as well as the existing regulatory emphasis on water (See, for example Chesapeake Executive Council 1983, and Chesapeake Bay Program 2004). The City's sustainability plan states clearly in its rationale for doubling its tree canopy: trees "reduce the amount of stormwater from running into the harbor" (Baltimore Sustainability Plan 2009).

Some organizations were more alike in their criteria preferences, and the affinity among organizations was not based upon whether the organization was a public agency, NGO, community group, or business (Figure 4).

3. Stakeholder Programs

a) Categories of Interest: The Types of Sites Where Organizations Work

The stakeholder survey asked questions about the urban forest categories on which groups worked. For instance, does the organization work on street trees, at schools, or in riparian areas? Street trees were the most popular category of interest (receiving 21.7 % of votes) followed by schools (15.9% of votes), with stream valleys - riparian buffers ranking third (13.0% of votes) (Figure 5). There was a disproportionate focus on street trees over residential lands. Yet, the City is predominantly private residential land area, most tree canopy is found on private residential, and most opportunities for tree planting are found on private residential lands (O'Neil-Dunne 2009).

Table 3. Stakeholder organizations and their preferences for different tree planting prioritization criteria. Numbers indicate the number of votes each criteria received by each organization. Each organization had 10 votes and were asked to distributed them across criteria to reflect their priorities. Acronyms are spelled out in Appendix 1.

	Percent Impervious Surface	Potential stewardship (positive)	Urban Heat Island using surface temperature	Stream corridors (1 ft buffer of each water element, sum area)	Schools, hospitals, libraries, recreation centers, and elderly care facilities	Life expectancy (Inverse)	Crime: Robbery, Burglary, Theft	Percent White (Inverse)	Road Density	Historic Districts	Transportation Connections	Critical Area	Population density (per square mile)	Percent of tree canopy that is over 5%	Percent Parks	Flood Plains (2 most risky)	Dependency Ratio	Toxic Releases Inventory
BCRP - Capital Development	1		1	1	1					2		1		1	1	1		
Office of Public Health Preparedness and Response (OPHPR)	1		2			1		2					1			1	2	
Baltimore Tree Trust	2	2	1	1	2	1		1										
Parks & People Foundation	2	1	1	1	1	1						1		1	1			
Department of General Services	2	1	1		1	1		1	1		1						1	
Bartlett Tree Experts	2	2	1	1	2				2									
Baltimore Medical System (E Baltimore)	2	1	2		3	2												
Department of Planning	2	3	3									1	1					
Baltimore Medical System (City)	1	3	3			2	1											
Mahan Rykiel		3		1	1					4	1							
The Friends of Wyman Park Dell	2	2				1				4					1			
CPHA							4	2			2		2					
Park Heights Renaissance					3		3	2			2							
Baltimore Office of Sustainability	3	1	2						1			1	1					1
SouthEast CDC	3	1	2						1		1		2					
Brooklyn and Curtis Bay Coalition, Inc.	3	1	1	1	1		2						1					
Patterson Park Neighborhood Association	5	2	2								1							
RK&K	5		1	3								1						
DOT	5		1	1							1	1				1		
Roland Park Civic League Greater Roland Park Master Plan Implementation (City)	4	1			1	1								2	1			
DPW	4	1		1	1	1						1				1		
Roland Park Civic League Greater Roland Park Master Plan Implementation (Roland Park)	3	3				1								3				
Wyndhurst Neighborhood	3	1	1				1	1	3									
Midtown Community Benefits District - Midtown Green	3						1	2	2			1			1			
BWB	3			7														
Criteria Totals	**61**	**29**	**25**	**18**	**17**	**12**	**12**	**11**	**10**	**10**	**9**	**8**	**8**	**7**	**5**	**4**	**3**	**1**

Major Criteria	Criteria Variables	Total Votes	Percentage of Total
Public Health &Safety	Life expectancy (Inverse[8])	12	4.8%
	Dependency Ratio	3	1.2%
	Urban Heat Island using surface temperature	25	10.0%
	Crime: Robbery, Burglary, Theft	12	4.8%
	Transportation Connections	9	3.6%
Environmental Justice	Toxic Releases Inventory	1	0.4%
	Percent White (Inverse[8])	11	4.4%
	Percent Parks	5	2.0%
Water Quality	Percent Impervious Surface	61	24.4%
	Stream corridors (100 ft buffer of each water element, sum area)	18	7.2%
	Flood Plains (2 most risky)	4	1.6%
	Critical Area	8	3.2%
Air Quality & Noise Pollution	Road Density	10	4.0%
Critical Places	Schools, hospitals, libraries, recreation centers, and elderly care facilities	17	6.8%
	Population density (per square mile)	8	3.2%
Community Presence	Potential stewardship (positive)	29	11.6%
Aesthetic	Restore Historical Sites	6	2.4%
Design	Historic Districts	4	1.6%
Replacement	Percent of tree canopy that is over 50%	7	2.8%

Table 4. The expressed preferences for each prioritization criteria summed across all workshop participants. Major criteria are summary categories that represent clusters or groupings of variables.

[8] Here inverse denotes that the variables algebraic sign was reversed. This is because lower life expectancies correspond to higher priority planting areas, for example.

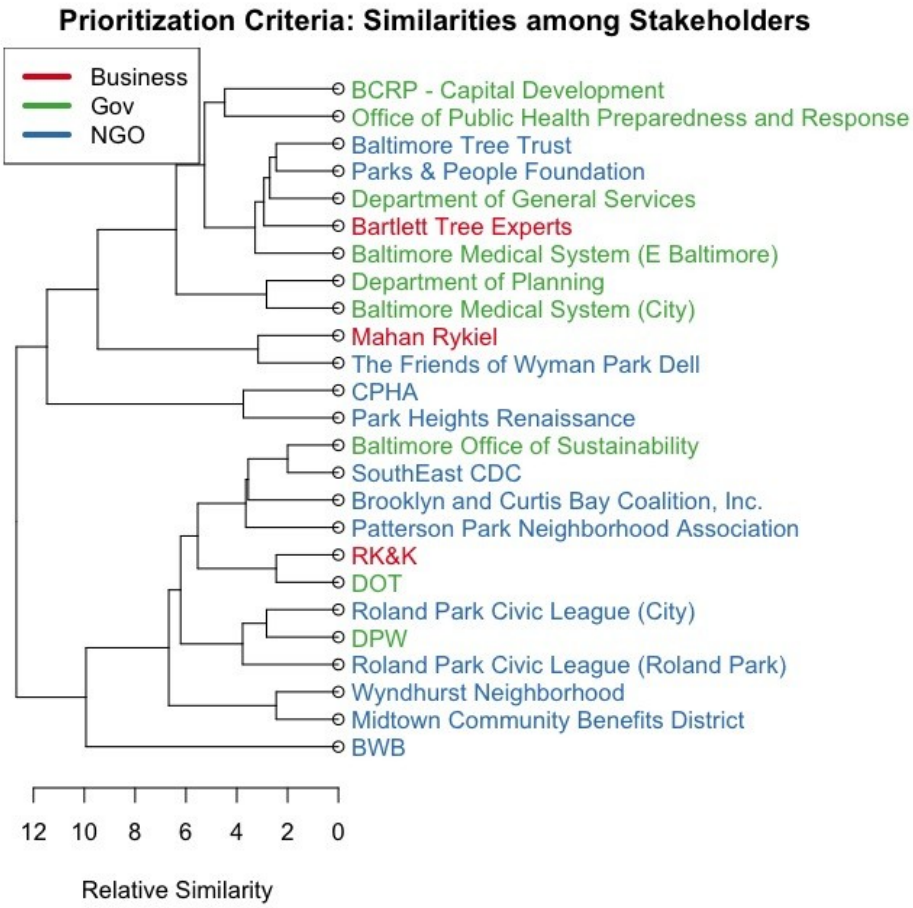

Figure 4. Hierarchical clustering helps highlight the relative similarities and differences across all prioritization criteria. Sectors are indicated by color. Data for Figure 4 can be accessed here.

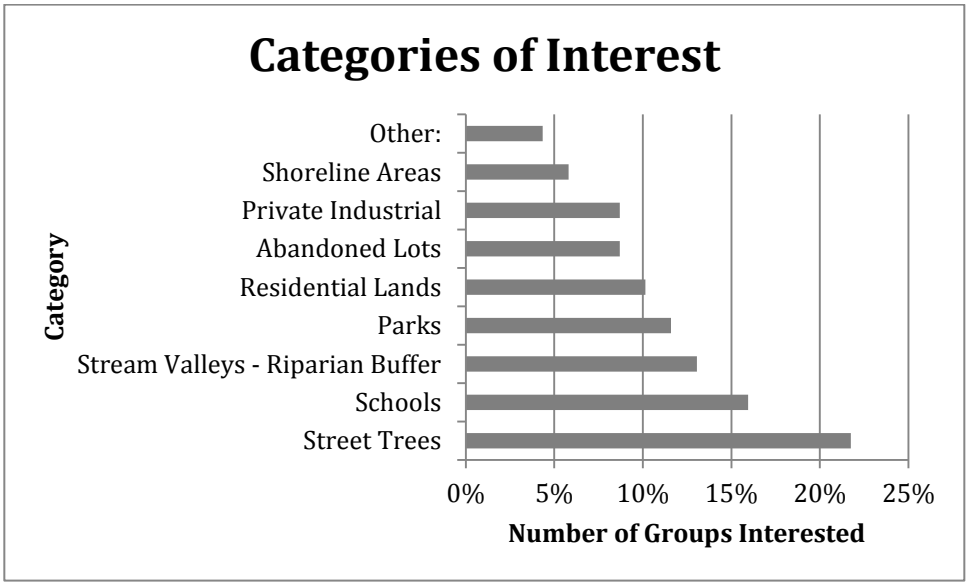

Figure 5. Categories of Interest (COI) as expressed by workshop attendees. Attendees could vote for items multiple times if they work across multiple COI's.

Survey results can be examined for similarities among organizations in terms of Categories of Interest (Figure 5). As was the case with Prioritization Criteria, similar types of organizations had diverse types of urban forest categories on which they worked, and different types of organizations worked on similar categories. For instance, the private consulting firm RK&K and Department of Public works worked on similar forest types, while the Departments of Public Works and General Services worked on different types. Figure 6 illustrates the specific similarities and differences. Both public agencies are involved in street tree planting, but the Department of Public Works also works on stream buffers and shorelines, while the Department of General Services concentrates on private industrial and residential lands.

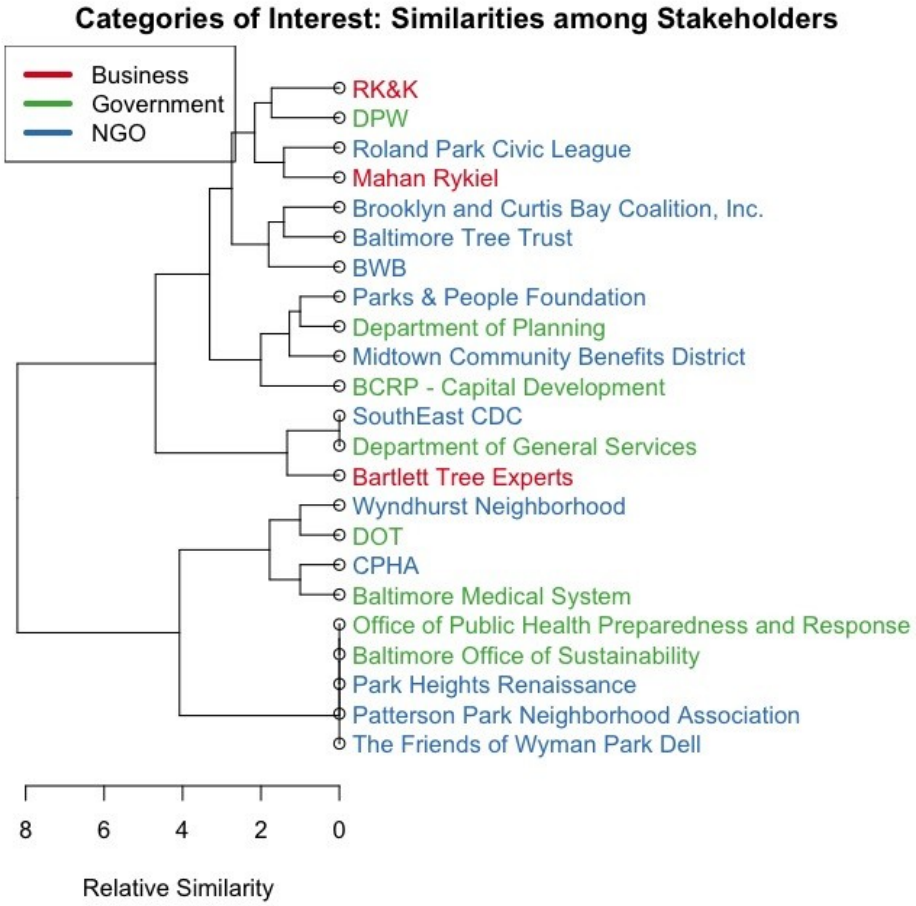

Figure 6. Hierarchical clustering helps highlight the relative similarities and differences across all Categories of Interest. Sectors are indicated by color, not all workshop participants completed the entire survey. Data for Figure 6 can be accessed here.

b) Areas of Interest: The Scale and Scope of Where Groups Work

Neighborhoods were the most popular type of area (receiving 29.4% of votes), followed by stakeholders who worked on a city-wide basis (26.5% of votes)(Figure 7). It is somewhat surprising that relatively few groups answered "watershed" as an area of focus given the high stated preferences for using trees to achieve water quality goals (Table 4) and the need for stormwater compliance. One manager offered an alternative explanation: managers know the

entire city drains into the Bay, so city or neighborhood might be synonymous with watershed because every place is part of a watershed.

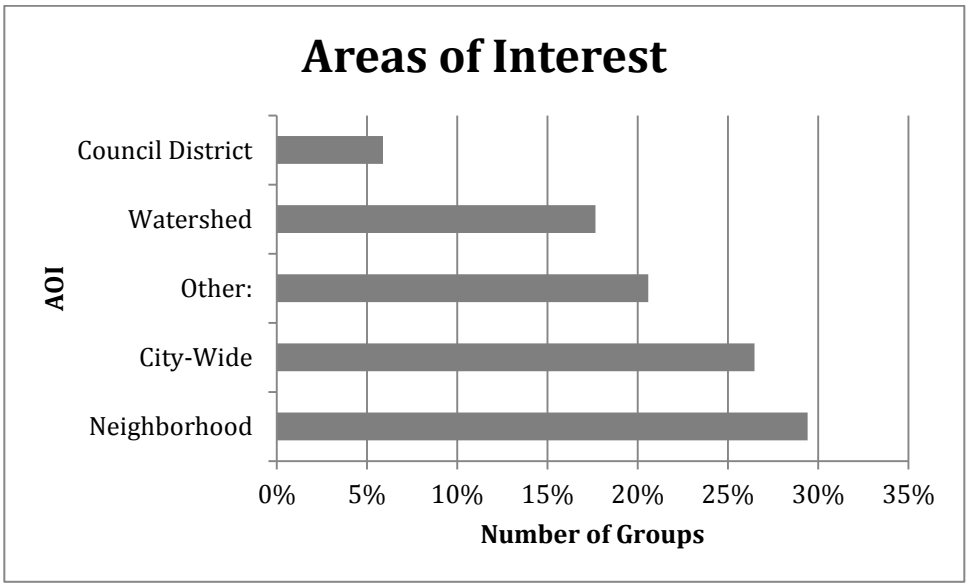

Figure 7. Areas of Interest (AOI) as expressed by workshop attendees. Attendees could vote for items multiple times if they work across multiple AOI's.

Stakeholders can be grouped based upon their Areas of Interest. The resulting groups are different from prioritization preferences or categories of interest. For instance, the two major, non-profit organizations—the Parks & People Foundation and BlueWater Baltimore—were very dissimilar in terms of prioritization preferences. In the case of Areas of Interest, however, they are nearly identical and form a group with the Department of Public Works. Unsurprisingly, almost all of the neighborhood organizations form a major branch of the tree diagram. Figure 8 permits examination of specific factors that cause organizations to be different or similar. Within the "neighborhood" branch, some neighborhood organizations focus on a specific neighborhood while others incorporate a collection or region of neighborhoods and have an associated watershed focus. At the bottom of the tree diagram are organizations that have a watershed and city-wide focus.

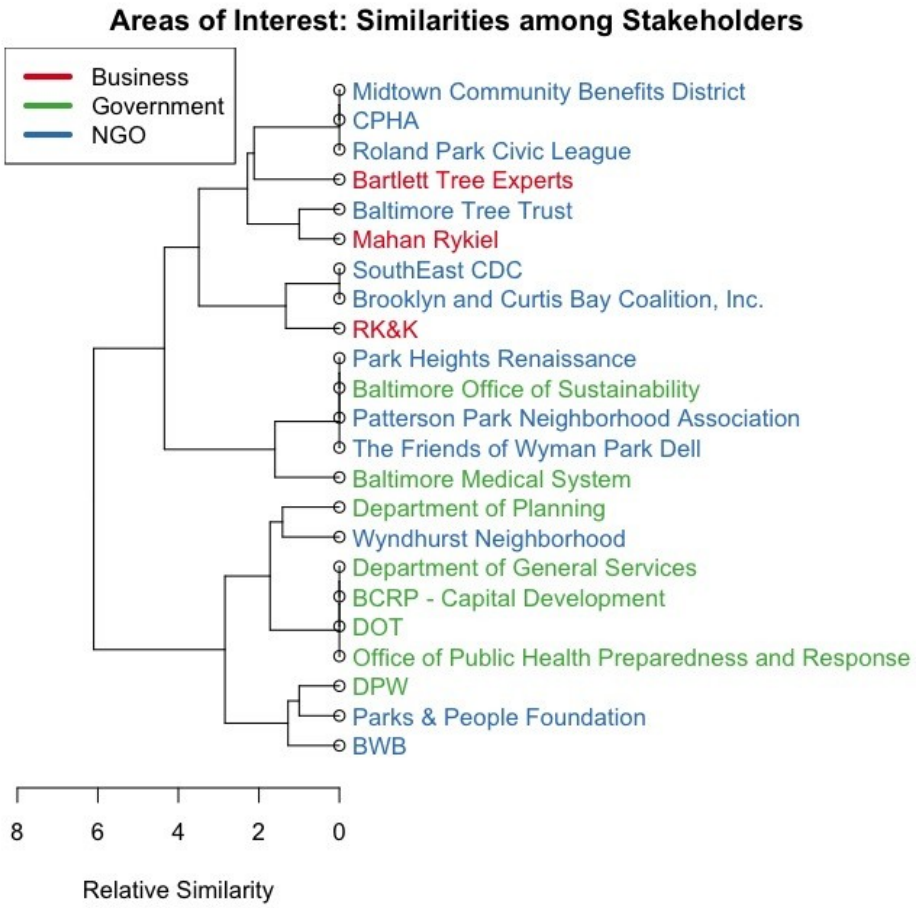

Figure 8. Hierarchical clustering helps highlight the relative similarities and differences across all Areas of Interest. Sectors are indicated by color, not all workshop participants completed the entire survey. Data for Figure 8 can be accessed here.

DISCUSSION

Opportunities for Coordination and Collaboration.

Opportunities for coordination and collaboration among stakeholders can be identified by analyzing the survey results in terms of groups. For instance, one can use the combination of prioritization mapping results, priority preferences, categories of interest, and areas of interest to ask, "which groups make a natural coalition to work in the high priority area of the Brooklyn and Curtis Bay region (mapping), focused on water issues (preference), addressing a combination of shoreline, street trees, schools, and residential areas (categories), and work on a neighborhood and watershed basis (areas)? Another example could be that a local energy company is interested to make school areas healthier by reducing extremely high local temperatures. The question could then be "which groups are most likely to work together on urban heat island (preference), focusing on schools (categories) in high priority UHI areas (mapping and areas)?"

Survey results can also be used to identify gaps in capacities and need for coalitions. For instance, few organizations work on private lands even though private property—as a type of owner—are the areas with the most land available for planting trees (O'Neil-Dunne, 2009).

These results can be used to identify high priority areas with significant residential tree planting opportunities (mapping) and to recruit groups who work on residential lands (categories).

Production of Maps and Databases

We learned several lessons about the production of maps and databases through our UTC Prioritization process. First, each organization was eager to receive a map of their prioritization preferences. It was important that the processing time for our UTC Prioritization tools were not time-intensive and that we could produce maps that were cartographically simple and self-explanatory (Figures 9 and 10 are shown as examples, Appendix 3 contains 26 maps, one for each organization plus a map created by summing all 25 participants' ten votes). Second, each organization wanted their map, the summary map of how all organizations' preferences overlapped in space regardless of individual organizations' preferences, and the individual maps from other organizations. The motivation for accessing all of these maps was so that each organization could see, spatially, how their preferences produced priority areas that might be similar or different from the overall preferences of the stakeholder group and other individual organizations. Third, organizations wanted to use their maps for reports and proposals. Thus, maps had to have a resolution appropriate for publication, yet small enough in terms of file size so that they could be manipulated in word processing programs.

Organizations wanted to be able to integrate the UTC prioritization data with their information systems. Our fourth lesson was that we produce our data at units of analysis and in formats that organizations could use. For example, both GIS data and Excel spreadsheets were provided in addition to maps. We created an FTP site so that maps and data could be downloaded as needed.

Finally, organizations can now use these maps to communicate internally and externally. Managers seeking additional funding and other resources within their organization may use a priority map to communicate an implementation strategy, while government officials can offer maps when explaining where they are planting and why. Sometimes areas within Baltimore were identified as high priority by different organizations for different reasons. These maps then allow organizations to see common cause based on location.

We have discussed the differences among organizations in terms of priorities, Categories, and Areas of Interest. Yet, one of the common observations in follow-up stakeholder meetings is that the groups tended to agree on the same locations, particularly for high priority areas (Appendix 3). This suggests that UTC prioritization tool can be used not only as a tool for identifying priority areas, but also as a tool for building consensus among stakeholder groups.

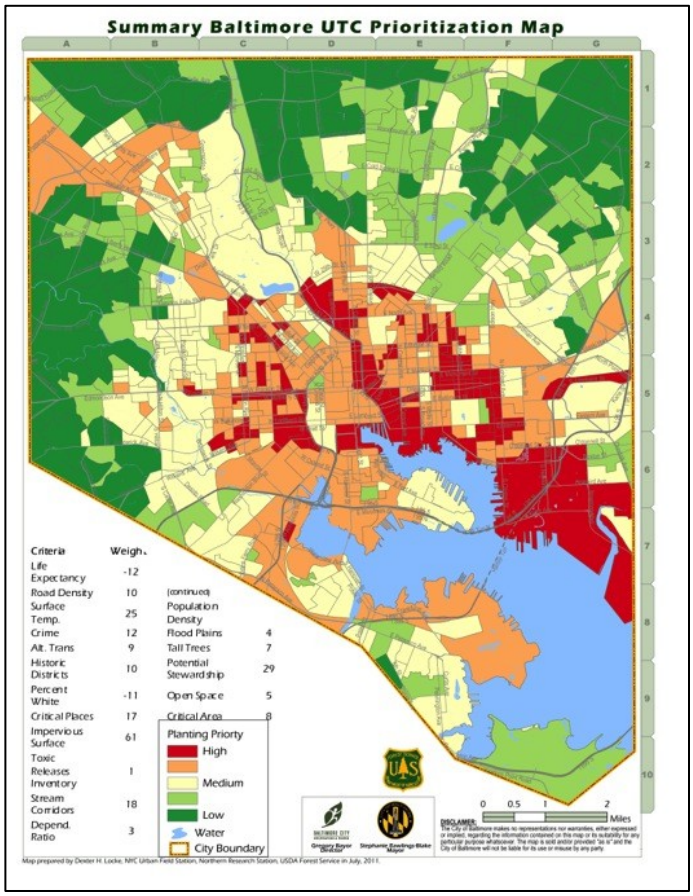

Figure 9. A sample map created by weighting Urban Tree Canopy Prioritization (UTC-P) criteria variables by one stakeholder's votes. See Appendix 3 for maps of all 25 stakeholder groups.

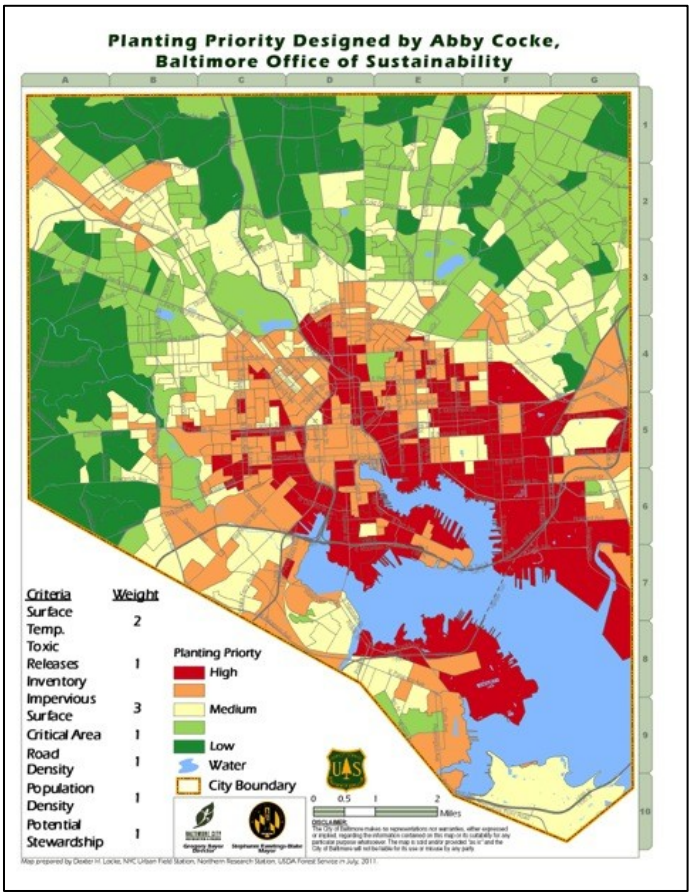

Figure 10. This map was created by summing up all 25 stakeholder's stated preferences for each criteria.

Linking Prioritization Analysis to other City Policy and Planning Initiatives

It may be important to link prioritization analyses to other policy and planning initiatives in a City. We created UTC prioritization maps for the City using Census Block Groups / Neighborhoods as the unit of analysis. This was effective for showing spatial variation with a familiar and useful social unit that is the basis for policy and planning.

The Department of Public Works is interested to explore how UTC prioritization can be used to implement its municipal stormwater utility. Specifically, UTC Prioritization maps can be used to target where to locate green infrastructure projects using stormwater utility revenue and to communicate how those stormwater utility fees are being strategically spent. Further, some landowners, particularly industrial landowners, may be interested to fund stormwater mitigation projects off-site in order to reduce their assessment. UTC Prioritization maps can also be used to identify potential sites and provide an opportunity for the industry to take "good citizen" credit for other UTC benefits, such as heat island mitigation, associated with the site.

The Department of Planning was interested to know how UTC priorities varied by its Housing Market Typology. The City's Housing Market Typology is the result of a cluster

analysis used to define categories of housing markets[9] and serves as a tool to help the City determine how it prioritizes investments and services. The five classes are Regional Choice, Middle Market Choice, Middle Market, Middle Market Stressed, and Distressed. We learned three things by linking the UTC prioritization with the City's Market Typology. First, even the City's highest quality neighborhoods (Regional Choice) had neighborhoods that were rated high priority for increasing UTC in the summary map with all groups votes combined (Figure 11). Each housing market type contains the range of UTC priorities when using the map containing the sum of all stakeholder's preferences. This combined UTC Prioritization and housing market analysis makes clear that areas which are high priority for UTC are not synonymous with poor or undesirable neighborhoods and that increasing tree canopy in high priority areas is not identical to addressing issues of environmental equity.

The second thing we learned by combining UTC and the City's Housing Market Typology is that UTC prioritization—its implementation and the coalitions who support it—can be used to further the City's larger agenda of urban stabilization and revitalization. Third, the motivations, preferences, and capacities for increasing tree canopy may vary among the housing markets that are also areas of high priority for increasing canopy. The following are two hypothetical examples. Households in Regional Choice neighborhoods may be motivated by property values, aesthetics, and stormwater mitigation. They may prefer small, flowering ornamental trees nearby, large shade trees and extensive lawns. They may plant trees on their own or work with a private landscape service. In contrast, households living in Distressed neighborhoods may be on a fixed income because they are retired or are on public assistance. They may not want to increase their property values because it may either lead to higher annual taxes, or because they do not own their home. But these residents may be motivated by aesthetics, job programs for youth, public health, and reducing trash and crime. They may prefer mid-size shade trees and planters since space might be more limited. They may be more likely to work with local churches, community associations, and non-profit organizations.

Additional Research Needs

Two major types of research needs were identified through the UTC Prioritization Process. The first type is methodological. Stakeholders asked if there was a way to identify trees that are in poor health or at risk of mortality because of insects or blights. Particularly, could we identify all the Ash trees, which are at risk of dying due to the Emerald Ash Borer? This is currently only possible using either field surveys, which are limited to public lands or private lands with the owner's permission, or through hyperspectral remote sensing techniques. Hyperspectral approaches are particularly attractive because they could be used to create a complete census of the landscape and, when combined with LiDAR, could quantify canopy cover by species, height, and condition. Hyperspectral approaches have been developed for rural forest areas. However, these areas tend to be relatively homogenous in terms of forest pattern and species diversity. Urban environments tend to be much more heterogeneous in spatial pattern and species diversity. Research is needed to determine the feasibility of hyperspectral sensors to map tree species and their attributes in urban environments and for these systems to be cost-effective.

[9]More about how the Planning Department created their housing typology was created can be found here, and the resultant data can be downloaded for free from here as a shapefile.

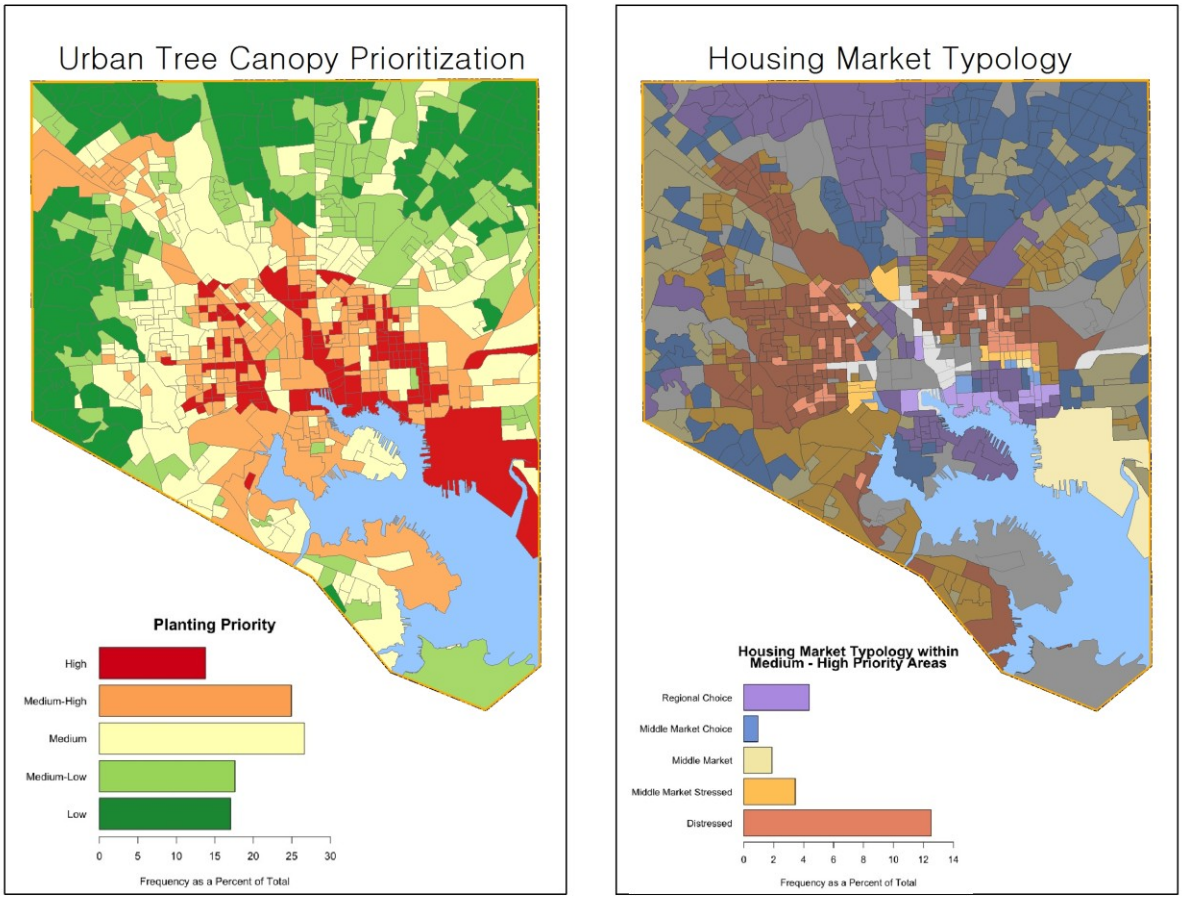

Figure 11. When only the high priority categories of UTC Prioritization map are shown, all five of Baltimore City's Housing Market Typology classes are found (right). High planting priority does not co-vary with the housing market. Different urban forestry strategies may be more effective in Regional Choice markets than in Distressed housing markets.

The second major type of research is theoretical: what social-ecological factors affect household motivations, preferences, and capacities to steward urban trees? Here, we use the term "steward" in reference to planting new trees or trees that have been either planted or grown through natural regeneration. Acts of stewardship involve a variety of behaviors that maximize the growth and minimize the loss of the urban canopy (Luley and Bond 2002). In the case of tree planting, novel approaches may be needed to increase tree canopy in high priority areas on community and private lands. Historically, public agencies have had limited jurisdiction for tree planting on private lands, and have focused their attention on public rights-of-way. To reach private landowners on private lands, public agencies have used tree programs that depended upon reactive approaches such as "first come, first served" tree giveaway programs. Who participates in these programs and why is an area of active research in Baltimore as well as Washington D.C. UTC high priority areas may not be areas with a high interest in tree planting on private land. Thus, market analysis research may need to be developed to better understand potential social, economic, and environmental motivations, preferences, and capacities of the community groups and residents associated with high priority UTC areas and low participation in tree giveaway programs (Grove et al. 2006b).

Market analysis research could benefit by examining household and neighborhood behaviors in the context of stewardship networks. Research on stewardship organizations and their networks is growing: factors affecting volunteerism in public parks (Fisher et al. 2010, Fisher et al. 2011), the organizational characteristics and degree of professionalization of civic environmental groups (Fisher et al. 2012), history of environmental stewardship organizations (Svendsen 2010; Connolly et al 2013), and their networks (Connolly et al 2013). Similar studies on the connections and collaborations among stewardship groups in Chicago (Belaire et al. 2011), Baltimore (Romolini under review), and Seattle (Wolf et al. 2011, Romolini under review) further extend this active area of research. This growing research has permitted cross-site analyses of stewardship networks and canopy cover in Seattle and Baltimore (Romolini, under review).

CONCLUSION

In this paper we have described the practical use of UTC Prioritizations tools in situations where there are a diverse set of stakeholders', whose interests spanned social, economic, and environmental issues. A transparent process was important to build confidence and trust among the stakeholders who participated, and to work toward a collaborative "All Lands, All People" vision that encompasses not just publicly funded activities on public land, but greening opportunities throughout the urban forest. An important step in the stakeholder process was a stakeholder survey that asked about what UTC services and benefits were important to them and their programs, the categories of forestry on which they focused, and the areas in which they were interested. Results from the survey were important for learning about the diverse community of stakeholders and identifying opportunities for coordination and collaboration and potential gaps in capacity. Results from the mapping process created prioritization areas, which was important for building consensus and coordination of limited resources among the stakeholders who participated.

The planning process described in this Baltimore example can be used in other cities, with local data and criteria adapted to meet the needs of urban forest managers, planners and sustainability goals. This process can used to advance the shift from planning for a Sanitary City to planning for a Sustainable City (Grove 2009, Pincetl 2009). Ultimately, UTC Prioritization can help groups transition from "tree people" to "sustainability people."

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APPENDIX 1: List of Organizations who attended UTC Prioritization Workshop

Individual on behalf of	Organization
Amy Gilder-Busatti	Baltimore Office of Sustainability/Department of Planning
Duncan Stuart	Department of Public Works
Abby Cocke	Baltimore Office of Sustainability
Justin Reel	RK&K
William Andersen	Baltimore City Recreation and Parks - Capital Development
Tom McGilloway	Mahan Rykiel
Tom McGilloway	The Friends of Wyman Park Dell
Anne Draddy	Department of General Services
Barbara Shea	Baltimore Tree Trust
Robbyn Lewis	Patterson Park Neighborhood Association
John Bishop	Wyndhurst Neighborhood
Fernando Guerra	Midtown Community Benefits District - Midtown Green
Mel Freeman	Citizens Planning and Housing Association, Inc.
Chad Vrany	Bartlett Tree Experts
Al Copp	Roland Park Civic League - Greater Roland Park Master Plan Implementation
Guy Hager	Parks & People Foundation
Robert I. Catlin, II	Brooklyn and Curtis Bay Coalition, Inc.
Rebecca Ruggles	Baltimore Medical System
Darin Crew	Blue Water Baltimore
Odessa Neale	Park Heights Renaissance
Jonathan Gross, MPH	Office of Public Health Preparedness and Response (OPHPR), Baltimore City Health Department
Kari Snyder	SouthEast Community Development Corporation
Valorie Lacore	Department Of Transportation
UTC Team	
Jarlath O'Neil-Dunne	University of Vermont, Spatial Analysis Laboratory
J. Morgan Grove	USDA Forest Service, Northern Research Station and Baltimore Ecosystem Study
Mike Galvin	SavATree Consulting Group
Dexter H. Locke	Graduate School of Geography, Clark University (formerly USDA Forest Service, Northern Research Station).

APPENDIX 2: Survey Instrument

Baltimore City TreeBaltimore Meeting:
UTC Prioritization Survey
Thursday, June 16th

1. **Contact information:** Name, Organization, Phone, Email
2. **UTC Prioritization**

You get 10 "Xs" to weight your priorities. You can vote more than once for your priorities.

Major Criteria	Criteria Variables	Priority Weightings
Public Health & Saftey	Life expectancy, mortality rate, mortality rate from heart disease, mortality rate from strokes, mortality rate from respiratory disease, mortality rate from diabetes, infant mortality rate	
	Asthma by zipcode	
	Dependency Ratio (< 18 + > 65) / sum >18 - <65	
	Urban Heat Island: surface temperature and solar exposure	
	Crime: Personal, Property and Total	
	Transportation Connections	
Environmental Justice	Toxic Releases Inventory	
	Brownfields	
	Poverty, Race, Home ownership	
	Percent Parks	
Water Quality	Percent Impervious Surface	
	Watershed H20 quality	
	Stream corridors	
	Flood Plains	
	Critical Area	
	Greenstreets	
	Blue alleys	
	Flooding	
Air Quality & Noise Pollution	(Major) Road Density	
Critical Places	Schools, hospitals, libraries, recreation centers, and elderly care facilities	
	Population density (per square mile)	
Community Presence	Potential stewardship	

3. Where do you work? ***Categories of Interest, please circle*:**

- Street Trees
- Abandoned Lots
- Private Residential Lands
- Private Industrial
- Parks
- Schools
- Stream Valleys – Riparian Areas
- Shoreline Areas
- Other

4. Where do you work? ***Areas of Interest, please specify name*:**

- Neighborhood
- Watershed
- Council Districts
- City
- Other

APPENDIX 3: The Map Gallery - contains 26 maps, one for each organization plus a map created by summing all 25 participants' ten votes. [http://digitalcommons.lmu.edu/cgi/viewcontent.cgi?filename=0&article=1132&context=cate&type=additional]