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Use of Urban Tree Canopy Assessments by Localities in the Chesapeake Bay Watershed

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Urban tree canopy (UTC) in the Chesapeake Bay watershed (CBW) provides numerous environmental, economic, and societal benefits. UTC assessments use remote sensing technology to deliver a comprehensive spatial snapshot of a locality's existing UTC. Because UTC assessments delineate the extent and location of tree canopy cover in the context of other land covers (including plantable space), they are important for establishing tree canopy goals, creating and implementing strategies to achieve those goals, and monitoring progress. Over the past decade, UTC assessments have been completed for numerous localities in the CBW as a result of the Chesapeake Bay Program identifying UTC as a key strategy for Bay restoration. Our research investigated the prevalence of UTC assessments within the CBW and studied how localities are using them. We conducted two surveys: 1) a pilot survey of Virginia localities that received UTC assessments as part of the Virginia UTC project; and 2) a comprehensive survey of all 101 localities in the CBW with populations over 2,500 for which a UTC assessment existed as of May 2013. Surprisingly, 33% of localities in the CBW reported being unaware that a UTC assessment had been performed for their jurisdiction. In general, counties and cities were more likely to be aware of the assessments than were towns (or their jurisdictional equivalent). Most localities that were aware of their assessment were using it in some manner for urban forest planning and management; however, the most frequent activities were also the most basic uses, including: educating officials or citizens about the importance of tree canopy (57%), providing a baseline for evaluating progress toward UTC goals (49%), creating a locality-wide tree canopy goal (47%), planning and prioritizing tree plantings (45%), and informing larger initiatives (43%). All other uses of the assessments (i.e., specialized uses) were reported by 33% or fewer of the CBW localities. Our findings point to the need for outreach to local governments about UTC assessments and their potential uses, particularly in light of increasing emphasis in the CBW on managing urban forests and optimizing UTC as a Bay restoration strategy.

Keywords
Urban forestry, urban planning, green infrastructure, canopy cover, GIS, remote sensing

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INTRODUCTION

The Chesapeake Bay watershed (CBW) covers portions of six states (DE, MD, NY, PA, VA, and WV) and the District of Columbia, encompassing over 166,000 km^2 and inhabited by nearly 18 million people (Chesapeake Bay Program 2012). It has undergone substantial urbanization and land cover change since European settlement. As a result of land conversion and loss of forest cover, high levels of nutrient and pollution runoff have led to a decline in the Chesapeake Bay's health and subsequent degradation of both its environmental and economic uses (Goetz et al. 2004).

Typically, as an area becomes more developed, urban tree canopy (UTC) decreases while impervious surface area increases (Nowak and Greenfield 2012). Between 1990 and 2000, impervious surface area within the CBW increased by 41%, with some localities losing as much as 17% of their UTC during that period (Jantz et al. 2005). More recently, Sexton et al. (2013) reported that between 1984 and 2010, impervious surface area in the Washington, D.C. and Baltimore, MD region specifically increased from 3.7% to 4.9% (an average increase of 11 km^2 per year). These development pressures are unlikely to abate in the near future, and impervious surface area is projected to increase in the CBW over the next 30 years (Theobald et al. 2009).

Loss of UTC and increase in impervious surface cover within an urban area can have negative environmental consequences for both local and regional watersheds. For example, impervious surface increases both the temperature and volume of stormwater runoff (Jantz et al. 2005). Tree canopy over pavement, in contrast, can reduce stormwater runoff temperatures (Jones et al. 2012), while tree canopies can also reduce stormwater volume and slow concentration time through interception (Xiao et al. 2000). Tree root channels also have potential to increase water infiltration rates through soil, thus helping reduce runoff in urban areas and potentially increasing groundwater recharge (Johnson and Lehmann 2006; Bartens et al. 2008). In some tree species, double-funneling may direct rainfall from the canopy to a concentrated area at the base of the tree (Schwärzel et al. 2012), thereby diverting stormwater away from impervious surfaces where pollutants – including nutrients – are often picked up and transported to water bodies (Goetz et al. 2004). Nutrient runoff in the CBW has a particularly significant impact on the Bay's nutrient status because of the high land area per volume of water ratio – the highest of all estuaries in the United States (Shuyler et al. 1995).

Beyond mitigating stormwater and nutrient runoff, municipalities and their citizens derive a variety of other environmental, economic, and social benefits from their UTC (Roy et al. 2012). Yet, the amount and distribution of UTC can influence the location and magnitude of many of these benefits. In the late 1990s and early 2000s, interest increased for more accurate mapping of land cover in the CBW to track changes in impervious surface area and forest cover (e.g., Chesapeake Executive Council, 2003; Chesapeake Bay Scientific and Technical Advisory Committee, 2004). These data were seen as integral to ecosystem models intended to inform more effective Bay restoration efforts (Goetz et al. 2004).

Procedures for urban tree canopy assessment (UTCA) were developed to help municipal planners and decision-makers understand their urban forest resource. The UTCA evaluates UTC within a defined geographic area using remote sensing tools and techniques (McGee et al. 2012).

Several dozen urban tree canopy assessments (UTCAs) have been performed for municipalities across the U.S. over the past decade, and many of those have been in the CBW (e.g., McGee 2012; Locke et al. 2013; USDA Forest Service 2013). A UTCA answers two basic questions: (1) where does UTC currently exist, and (2) where is additional UTC possible? This data can be combined with existing geographic information such as parcel boundaries or zoning designations to generate statistics and answer questions about the distribution of UTC within a defined area (Rodbell and Marshall 2009; McGee et al. 2012). Municipal planners and decision-makers can then establish data-driven UTC goals; create and implement strategies to achieve those goals; and monitor and evaluate progress toward those goals.

The Chesapeake Bay Program (CBP), a regional partnership dedicated to restoration and protection of the Bay, has identified expansion of UTC as a key strategy to improve Bay health. The CBP, which includes federal and state agencies, local governments, non-profit organizations, and academic institutions, has committed to assisting 120 communities in the CBW with adopting UTC expansion goals by 2020 (USDA Forest Service 2012). Though not a regulatory body, the CBP is working towards "increases in the amount of tree canopy in all urban and suburban areas by promoting the adoption of tree canopy goals as a tool for communities in watershed planning" (Chesapeake Executive Council 2003). Performing a UTCA is viewed as an essential first step for establishing a UTC goal (Raciti et al. 2006). Each CBP partner uses its own resources to implement Bay restoration and protection activities. As such, performing UTCAs has been left up to each state's Urban and Community Forestry program, and each state decides how to engage communities in conducting and utilizing UTCAs (Julie Mawhorter, personal communication, Jan. 28, 2013).

Though there has been substantial investment in performing UTCAs within the CBW and across the U.S., there has been limited investigation into how UTCAs are employed by local governments. Previous literature has primarily focused on demonstrating how localities could use UTCAs as decision-support and planning tools (Locke et al. 2011; McGee et al. 2012; Locke et al. 2013) and for informing local policy (Raciti et al. 2006; Wiseman and McGee 2010). However, it is not evident whether local governments are actually using UTCAs for urban forest policy, planning, and management. As a result, it is unclear whether ongoing investment in UTCAs is an impactful strategy for enhancing UTC in the CBW.

We conducted a study of localities in the CBW to gain insight on the prevalence and use of UTCAs by local governments. We first conducted a pilot survey of localities in Virginia to ground our understanding of the issues and then used that information to craft a survey on UTCA usage that was administered to personnel in local governments throughout the CBW where UTCAs were known to have been performed. Because local governments are defined by various states in diverse ways, the term "locality" is used throughout this paper as a broad term encompassing any type of local government entity, whether it be a city, a town, a county, or other administrative unit. The purpose of this study was to determine how many localities in the CBW knew that a UTCA had been performed for their jurisdiction and to study how UTCAs were being used for urban forest planning activities such as setting UTC goals, creating and implementing strategies to achieve those goals, and monitoring their progress.

METHODS

Our study of UTCAs in the CBW comprised two surveys of local government personnel. First, a short, qualitative survey was conducted within Virginia to explore and contextualize possible UTCA uses for urban forest planning. Using these findings, we designed and administered a comprehensive, quantitative survey of localities throughout the entire CBW. Both surveys were conducted with oversight by the Institutional Review Board at Virginia Tech for compliance with standards for respondent anonymity and confidentiality. Described below are the methods used in designing, administering, and analyzing both of these surveys.

Pilot Survey of Localities in Virginia

To understand how localities in the CBW use UTCAs, we first conducted exploratory research in Virginia. Virginia accounts for the largest proportion of land area and population in the CBW, with nearly 75% of its population living in the watershed (USDA Natural Resources Conservation Service n.d.). In 2007, the Virginia Department of Forestry commissioned the Virginia UTC Project in partnership with Virginia Tech and University of Vermont Spatial Analysis Laboratory. The purpose of this project was to provide technical and financial support for 26 Virginia localities to perform a UTCA within their jurisdiction (McGee et al. 2012). We surveyed municipal employees of these 26 localities (20 of which are located in the CBW) and requested open comments regarding how they had been using their UTCA since its completion. This web-based survey was administered between December 2012 and January 2013. To get broad perspectives on UTCA use, the survey was sent to multiple municipal employees in each locality and included a diversity of professional roles. Contact information for these survey respondents was gathered through consultation with the state Urban and Community Forester, by municipal directories on the internet, and by directly inquiring with localities.

To maximize our response, the survey was administered using the Dillman Total Design Method, including an introductory email requesting survey participation, followed by an email with survey instructions, and then a maximum of two reminder emails for those yet to complete the survey (Dillman 2000). The survey asked open-ended questions such as, "Describe how your locality is using its UTCA", and "in addition to any current uses, describe some ways that you think your locality should use its UTCA". These open-ended questions were used to capture nuanced input from respondents to improve our depth of understanding about the extent and sophistication of UTCA use (McLean et al. 2007). Upon completion of the survey, the responses were carefully reviewed and qualitatively coded (in vivo, inductive coding) into a distilled set of themes based on commonalities amongst the responses. From these themes, we then structured a set of 17 potential UTCA uses, which were grounded in our review of the literature on urban forest policy, planning, and management.

The results of this pilot survey were ultimately used in two ways. First, the list of potential uses was vetted with urban forestry professionals familiar with UTCAs and then included in the subsequent survey of all localities in the CBW with UTCAs (the CBW survey). Second, selected responses representative of the potential UTCA uses that were queried in the CBW survey have been used in this paper as qualitative examples to contextualize the quantitative CBW survey results.

Comprehensive Survey of Localities in the Chesapeake Bay Watershed

We used ArcGIS Explorer Online (ESRI, Redlands, CA) and U.S. Census Bureau data to identify a total of 440 localities (87 cities, 165 counties, and 188 towns) with a population over 2,500 that had land area either partly or completely within the CBW (ESRI 2013; US Census Bureau 2014). Simultaneously, we developed a list of localities with completed UTCAs as of May 2013 by contacting the Urban and Community Forester for each state, the CBP, and universities and private companies known to have performed UTCAs. We then crosschecked the list of localities in the CBW with the list of localities with completed UTCAs. We identified 55 UTCAs covering 101 localities (see Appendix A for the list of localities), including 42 cities, 12 counties, and 47 towns. Localities with UTCAs represented 9.2% of the land area within the CBW.

Due to differences in administrative subdivisions between the states, we chose to group localities into three categories: county, city, and town. For the purposes of analysis, boroughs (PA) were considered towns, and corporations (WV) and the capital district (Washington, D.C.) were considered cities. We made no distinction between independent cities and regular cities. Townships, a sub-county level administrative unit in PA, were excluded because they are typically small (<10,000 people), lack more than a few employees, and do not have an equivalent administrative unit in other states. There were no localities in the CBW portion of New York with a UTCA.

Chesapeake Bay Watershed Survey Respondents

For each locality, we purposefully selected one respondent to complete the survey via either a search of the locality's website or by contacting the locality directly. The ideal survey respondent was an individual who was (1) knowledgeable (or most knowledgeable) about use of the locality's UTCA; (2) had a broad understanding of the local urban forestry program (if any); (3) held a planning or management position; or (4) could make decisions in an official capacity about use of the UTCA. Depending on the locality, the official role of the actual respondent varied and included arborists, urban foresters, planners, and town or city managers. To confirm that the most qualified individual had been identified, the person was contacted via telephone to discuss their attributes and willingness to participate. Of the 101 localities contacted in the CBW, individuals in three localities stated during phone conversations that "matters of trees or land use planning" were dealt with at the county level and that they did not wish to participate in the survey.

Chesapeake Bay Watershed Survey Design

The web-based CBW survey included an initial screening question asking whether the respondent was aware of that a UTCA had been performed for the locality. If the respondent answered 'no', it was assumed the UTCA was not being used by the locality. Because we had documented that a UTCA had been performed in each locality, we were confident that an assessment existed, though the locality may not have had access to, or been aware of, the data at the local level. Localities that indicated that they were unaware of their UTCA were subsequently asked only survey questions about characteristics of the local urban forestry program (see Appendix B for urban forestry program characteristics).

Based on our evaluation and thematic grouping of the qualitative responses to the pilot survey of Virginia localities, a list of 17 potential UTCA uses was created and modified with input from urban forestry professionals familiar with UTCAs (Table 1). CBW survey respondents who indicated in the screening question that they were aware that a UTCA existed for their jurisdiction were then asked if their locality was using the UTCA for each of the 17 activities. The respondents could reply “Yes”, “No”, or “Don’t Know”. We piloted the CBW survey with several urban forestry professionals to identify and correct ambiguities and to refine questions. The survey was administered online in July 2013 using the Qualtrics Research Suite (Qualtrics, Provo, UT) and again following the method of Dillman (2000) described above.

To aid our understanding of how UTCA were being used by localities, the 17 potential UTCA uses were categorized based on the four stages of the urban forest planning model described by Miller (2007): (1) resource assessment; (2) goal setting; (3) management plans; and (4) evaluation and feedback. In the UTC context, these stages correspond with (1) conducting a UTCA; (2) UTC goal setting; (3) UTC implementation strategies; and (4) UTC monitoring and evaluation (Table 1). We further divided Stage 3 – UTC Implementation Strategies – into three categories based on the types of activities described by respondents to the Virginia survey: (1) public buy-in, (2) prioritization, and (3) policies and land-use planning.

RESULTS AND DISCUSSION

Responses to Pilot Survey of Localities in Virginia

Initially, 121 individuals from 26 localities in Virginia were contacted; however, 42 individuals indicated that someone else we had already contacted was more qualified to respond. Of the remaining 79 individuals, 58 completed surveys were received for a 73% response rate (in several instances, there were multiple respondents per locality). Of the 58 individual respondents, we identified 32% as resource managers, 27% as planners, 22% as GIS specialists, and 20% as administrators based on their official job title. At least one individual responded to the survey for 24 of the 26 localities, yielding a 92% response rate from the localities. Responding localities ranged in size from 4,895 to 437,994 people and had a population density from 243 to 3,208 people/km^2.

Responses to Comprehensive Survey of Localities in the Chesapeake Bay Watershed

Of the 98 surveys that were sent out, 55 were returned. Four surveys provided incomplete data and were thus excluded from further analysis, resulting in a 52% adjusted response rate. In total, 51 completed surveys representing 24 cities, 9 counties, and 18 towns were analyzed (Table 2). An assessment for response bias was performed by comparing the distribution of the localities that responded to the survey versus the distribution of the entire sampling frame solicited for the survey. No statistically significant difference ($\alpha = 0.05$) was found between the survey respondents and the sampling frame when compared by state, locality type, or population size. Although non-respondents were not systematically evaluated at the conclusion of the survey, the high response rate (52%) and very high respondent geographical coverage (responding localities accounted for 81% of the total land area of CBW localities possessing a UTCA) gave a strong indication that a representative response had been obtained from the survey.

Awareness of UTC Assessments in the Chesapeake Bay Watershed

Only 34 of the 51 respondents in the CBW survey (67%) indicated they were aware that a UTCA had been performed for their locality. County respondents seemed to be the most aware (89%), whereas only 33% of town respondents were aware (Table 3). We were surprised that a substantial proportion (33%) of localities overall were unaware that a UTCA existed for their jurisdiction. Because this was unexpected, the survey was not designed to identify reasons that respondents were unaware of their locality's UTCA. However, we propose a few potential explanations: (1) no one in the locality was informed that the assessment had occurred; (2) the information was disregarded or not effectively disseminated across key departments within the locality, perhaps due to lack of awareness or lack of expertise about urban forestry within the locality; (3) lack of "institutional memory" of the UTCA because of a significant change in staffing or record-keeping since the time of the UTCA; or (4) the survey respondent was not the appropriate individual to contact and was not aware that other individuals or departments within the locality were using the UTCA. We made efforts to reduce the likelihood that we were unable to identify the most appropriate respondent for the survey by asking our initial locality contacts for a referral if they did not have familiarity with the UTCA. Based on our knowledge of the origins of the UTCAs, we attribute some of this lack of awareness to the fact that several UTCAs were conducted at the county-wide scale, and therefore it is possible that data existed for some towns without their direct participation or knowledge. Though we cannot assume that these smaller localities would use UTCAs even if they were aware of them, we did find evidence of usage among some small localities, suggesting that it is possible. The need to engage smaller localities that already have UTCAs conducted at the county-level is clear. It is also evident that additional efforts should focus on communicating potential usefulness of existing UTCAs to smaller localities.

Uses of UTC Assessments in the Chesapeake Bay Watershed

Overall trends in UTC assessment use

Only respondents that said they were aware of their locality's UTCA were asked whether or not their locality had used their UTCA for each of the 17 potential uses (Table 1). The most frequently reported uses included: *educating officials or citizens about the importance of tree canopy* (57%), *providing a baseline for evaluating progress toward UTC goals* (49%), *creating a locality-wide tree canopy goal* (47%), *planning and prioritizing tree plantings* (45%), and *informing larger initiatives* (43%). Observed patterns in the results were used to create a conceptual model of UTCA usage that separated activities into general and specialized uses within each stage of Miller's (2007) urban forest planning model (Figure 1). For example, localities that reported a specialized use of the UTCA also reported performing the general use within the same stage of the planning model. About 33% of CBW localities reported six or more uses of their UTCA.

Table 1. List of 17 potential uses of an urban tree canopy assessment (UTCA) asked about in the survey of localities in the Chesapeake Bay watershed, categorized by stages in the urban forest planning model of Miller (2007). Excerpts from the pilot survey of localities in the Virginia UTC Project are provided to contextualize each potential use.

Stage		Potential Uses of UTCA in Urban Forestry	Excerpts from Virginia Survey Responses
UTC Goal Setting		Create a locality-wide UTC goal	*"the assessment was considered when setting a UTC goal"*
		Develop UTC goals based on land use, zoning or other fine-scale criteria	*"setting canopy goals based on land-use types and available planting spaces"*
UTC Implementation	Public Buy-In	Educate public officials or citizens about the importance of UTC	*"information is being used in education of public officials about value of trees"*
		Engage the public with local urban forestry (e.g., volunteer recruitment, partnerships)	(no relevant excerpts)
		Justify funding requests or leverage additional funding	*"used in attempt to obtain funds for maintenance of existing trees on public right of ways"*
	Prioritization	Plan and prioritize tree plantings	*"identify potential locations where trees may be planted to increase city canopy coverage"*
		Plan and prioritize existing UTC conservation	(no relevant excerpts)
		Plan and prioritize outreach to specific neighborhoods or districts based on UTC cover	*"targeting neighborhoods with lower tree canopy for outreach…and for participation in various programs to get more trees planted on private property"*
	Policies and Land Use Planning	Inform larger initiatives (e.g., sustainability plans, watershed implementation plans, green infrastructure plans, comprehensive plans)	*"included the analysis in the updated comprehensive plan and hope to use it in some way to promote additional vegetative cover"*
		Inform land-use planning and zoning with appropriate green infrastructure considerations	*"identify opportunities to mitigate fragmentation of woodland and forest communities through reforestation"*
		Guide requirements for tree conservation during site development and re-development	(no relevant excerpts)
		Inform the creation or revision of policies (e.g., zoning, taxation, ordinances)	*"revisions to the existing zoning ordinances requiring a greater level of tree canopy for new construction of residential and commercial properties"*
		Enforce tree ordinances or site development requirements	*"help monitor the effectiveness of our local tree conservation ordinance during land development"*
UTC Monitoring and Evaluation		Provide a baseline for evaluating progress toward UTC goals	*"it gives us a good benchmark of existing conditions so that we have something to measure our success by in 10 years"*
		Evaluate potential impacts of UTC gains or losses	*"[environmental benefit estimates] are used for economic development purposes as well as measuring environmental improvement"*
		Demonstrate compliance with air quality management goals or requirements (e.g. SIPs)	(no relevant excerpts)
		Demonstrate compliance with stormwater management goals or requirements (e.g. MS4s, WIPs)	*"to determine stormwater management potential in areas designated by Chesapeake Bay Protection Act and subject to TMDL requirements"*

Table 2. Characteristics of 51 localities in the Chesapeake Bay watershed that responded to a survey about their use of an urban tree canopy assessment performed for their jurisdiction (52% adjusted survey response rate).

Characteristics of Responding Localities	Minimum	Median	Maximum
Land area (all localities) | km^2	**1**	**249**	**2,458**
Land area (towns)	1	13	44
Land area (cities)	5	106	906
Land area (counties)	544	1,093	2,458
Population (all localities) | people	**2,548**	**130,815**	**1,081,726**
Population (towns)	2,548	9,488	42,616
Population (cities)	5,259	115,840	620,961
Population (counties)	53,498	413,404	1,081,726
Population density (all localities) | people/km^2	**78**	**1,108**	**3,976**
Population density (towns)	158	969	1,968
Population density (cities)	243	1,491	3,976
Population density (counties)	78	367	1,057

Table 3. Localities in the Chesapeake Bay watershed reporting that they were aware that an urban tree canopy assessment (UTCA) had been performed for their jurisdiction. Data are from a survey of 98 localities, to which 51 localities responded (52% adjusted response rate). States for which a locality type was not represented in the survey are listed as N/A.

	Locality Awareness of UTCA – Percent (Count)			
State	Counties	Cities	Towns	Overall Average
District of Columbia	N/A	100% (1/1)	N/A	**100% (1/1)**
Delaware	N/A	0% (0/1)	100% (1/1)	**50% (1/2)**
Maryland	100% (5/5)	92% (11/12)	50% (2/4)	**86% (18/21)**
Pennsylvania	100% (1/1)	50% (1/2)	11% (1/9)	**25% (3/12)**
Virginia	100% (1/1)	86% (6/7)	50% (2/4)	**75% (9/12)**
West Virginia	50% (1/2)	100% (1/1)	N/A	**67% (2/3)**
Overall Average	**89% (8/9)**	**83% (20/24)**	**33% (6/18)**	**67% (34/51)**

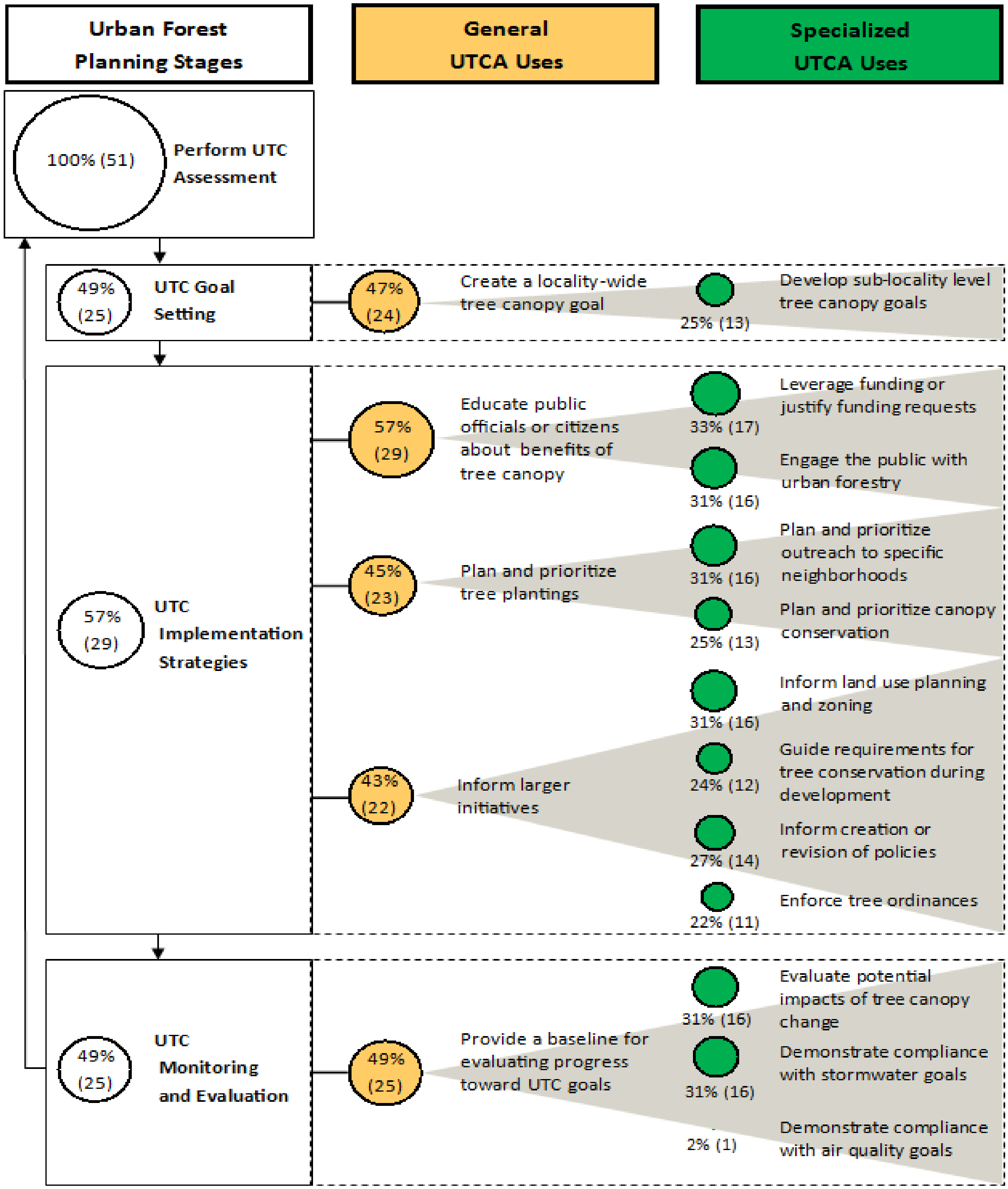

Figure 1. Prevalence of urban tree canopy assessment (UTCA) use reported by 51 localities in the Chesapeake Bay watershed when surveyed about 17 pre-defined uses (yellow and green circles). White circles correspond to stages of the urban forest planning model (Miller 2007). Circle size is proportionate to the percentage (count) of responding localities. Specialized uses do not necessarily sum to general uses because a single respondent could report multiple specialized uses within a general use.

UTC assessment use for tree canopy goal setting

Overall, 47% of CBW survey respondents stated that their locality had used the UTCA to *create a locality-wide tree canopy goal*. While most respondents to the Virginia survey simply mentioned that the UTCA was considered in goal setting, one said that the assessment was used to "calculate how many trees will need to be planted to attain our stated goal" in order to determine if the goal was achievable. An important part of setting realistic and achievable goals for UTC is to understand existing and possible UTC and the resources required to achieve those goals. For example, in 2007, the city of Charlottesville, VA set a UTC goal of 40%; however, in 2009, results from a UTCA of the city based on 2007 data showed that UTC in the city was actually over 46% (City of Charlottesville 2009). This illustrates the need for data-driven goals and decision-making.

Even fewer respondents (25%) reported that their locality was using the UTCA for in-depth goal setting: to *develop tree canopy goals based on land-use, zoning or other fine-scale criteria*. Because a variety of factors can correlate with UTC – socioeconomic demographics (Iverson and Cook 2000; Troy et al. 2007; Landry and Chakraborty 2009), topography, and age of housing stock (Heynen and Lindsey 2003), it may be worthwhile to create sub-locality goals for particular areas based on land use, environmental data, or socioeconomic characteristics. Szantoi et al. (2012) argued for localized UTC goals that take into account socioeconomic variability across different areas. Similarly, American Forests, a nonprofit advocacy group, suggests adjusting UTC goals based on land use types: 50% UTC in suburban residential; 35% in urban residential; 25% in commercial and mixed use or industrial; and 15% in central business districts (American Forests 2008). Finer-scale goals are typically recommended because different land uses and land use densities (e.g., suburban versus high-density residential) likely have both different existing and possible UTC (Mincey et al. 2013).

UTC assessment use for tree canopy implementation strategies

In the CBW survey, 57% of the localities indicated that they were using the information from the UTCA to *educate public officials or citizens about the importance of tree canopy*. When decision-makers understand the value of UTC, the urban forestry program for that locality is more likely to be successful (Lewis and Boulahanis 2008). Moreover, the spatial distribution of UTC can provide decision-makers with additional information to support policy development that addresses the drivers of inequities in UTC distribution. Respondents to the Virginia survey made statements about using the UTCA for education such as, "the UTC [assessment] is used for public education and outreach on the state of [our] urban forest and the value of trees".

Use of the UTCA for complex public engagement purposes was not as common among CBW survey respondents; 31% of respondents reported using the UTCA to *engage the public with local urban forestry* (e.g., *volunteer recruitment or partnerships*). Public participation in achieving UTC goals is essential for success. In Baltimore, for example, as of 2007 the city had 27% UTC but a goal of 40% by 2040. The UTCA showed that private residents owned the majority of existing UTC as well as the majority of tree planting spaces for additional canopy. Therefore, in order to achieve their stated UTC goal, the city needs to engage residents in the goal and inform them of the importance of their contribution to UTC conservation and enhancement (Baltimore Commission on Sustainability 2009; O'Neil-Dunne 2009; Locke et al. 2013).

Only 33% of respondents stated that their locality was using the UTCA to *leverage additional funding or justify funding requests*. Because communities have limited budgets, decision-makers may be more willing to invest in UTC if they understand the economic benefits of that investment for their constituents (Lewis and Boulahanis 2008). One respondent to the Virginia survey said that “UTC information is being used in an attempt to obtain funds for maintenance of existing trees on public right-of-ways”. Clearly, UTCAs are underutilized for this purpose in the CBW. Localities may also find their UTCA useful for writing competitive grant applications and substantiating internal funding requests. For example, St. Louis, MO is using its UTCA to raise awareness about the benefits of its urban forest and leverage additional funding for a broader St. Louis regional UTCA (Coble and Walsh 2012).

Results from the CBW survey showed that 45% of localities were using the UTCA to *plan and prioritize tree plantings*. Typical responses from the Virginia survey suggest that there is an opportunity to use more sophisticated prioritization techniques beyond simply identifying available planting space that will, as stated by one respondent, have “the greatest impact on our overall UTC percentage”. The benefit of increasing overall UTC in a city is tied to the environmental and social benefits trees provide; as such, an opportunity exists to prioritize tree plantings to maximize benefits rather than simply to increase UTC for its own sake. Locke et al. (2011) demonstrated how New York City’s UTCA can be used to prioritize tree plantings to mitigate various issues within a city, including flooding, noise pollution, and public health challenges. At the other end of the spectrum, UTCAs also can be used to prioritize conservation of existing tree canopy in comprehensive plans or other regional greenspace planning. Surprisingly, we found that substantially fewer localities (25%) were using their UTCA to *plan and prioritize canopy conservation*, suggesting that tree conservation may be a more complex or lower-priority activity than tree planting.

Additionally, 31% of CBW localities were using the UTCA to *plan and prioritize outreach to specific neighborhoods or districts based on tree canopy cover*. One Virginia respondent said their locality was using its UTCA “for targeting neighborhoods with lower tree canopy for outreach and awareness on the value of planting and preserving trees...and to target those areas for participation in various programs”. Across the country, other communities are also using their UTCA for prioritizing outreach. For example, the Indianapolis Neighborhood Woods Planting targeted neighborhoods with low UTC and high available planting space (Wilson and Lindsey 2009). In St. Louis, Forest ReLeaf of Missouri has used a local UTCA to prioritize tree planting locations for a tree planting plan (Coble and Walsh 2012).

Municipal resource managers can only directly manage trees (i.e., plant and maintain trees) on municipal public lands, including right-of-ways, parks, and grounds of public buildings. Since the majority of land in urban areas is often private residential, commercial, or industrial lands, resource managers must use a different suite of tools and tactics to indirectly manage trees on these lands. Among these tools are various policies and incentives such as comprehensive plans, zoning ordinances, tree ordinances, and development credits, some of which have been shown to have an effect on UTC (Hill et al. 2010). In our study, 43% of CBW localities were using their UTCA to *inform larger initiatives (e.g., sustainability plans, watershed implementation plans, green infrastructure plans, and comprehensive plans)*. Fewer (31%) said they used the UTCA in a specialized manner to *inform land use planning and zoning with appropriate green infrastructure considerations*. As an example, one Virginia respondent said they were using their UTCA to "identify opportunities to mitigate fragmentation of woodland and forest communities through reforestation".

Researchers in Georgia found that certain tree ordinances, zoning ordinances, and smart growth projects can be effective for preserving UTC in communities (Hill et al. 2010). In the CBW survey, 27% of respondents reported that their locality used its UTCA to *inform the creation or revision of policies such as zoning or tree ordinances*. One Virginia survey respondent stated that their locality is in the process of "revisions to the existing zoning ordinances requiring a greater level of tree canopy for new construction of residential and commercial properties." Also in the CBW survey, 24% of respondents reported using their UTCA to *guide requirements for tree planting or canopy preservation during site development*. A Virginia survey respondent alluded to this activity by stating their locality was using it "to increase new landscaping zoning ordinances on private property." We found 22% of CBW localities reported using the UTCA to *enforce tree ordinances or site development requirements*. By performing sequential UTCAs, it is possible to analyze UTC change through time and evaluate the effectiveness of various policies such as tree protection ordinances (McGee et al. 2012).

One of the most basic, yet informative uses of a UTCA is developing a baseline for a locality's UTC in order to evaluate future changes and monitor progress toward UTC goals. Without baseline data and periodic reassessment as a means to monitor progress toward goals, it is virtually impossible to know if management efforts are working (Dwyer et al. 2000). Nearly half (49%) of respondents to the CBW survey said their UTCA was used to *provide a baseline for evaluating progress toward tree canopy goals*. One respondent to the Virginia survey said, "the UTCA not only gives us guidance where trees are needed, but it gives us a good benchmark of existing conditions so that we have something to measure our success by in 10 years or more." A UTCA must be repeated over time to evaluate change in UTC at the locality-wide and finer scales.

Once the amount of UTC is known, decision-makers can evaluate the potential environmental or policy consequences under scenarios in which UTC increases or decreases and thereby weigh the costs and benefits of various management options. In the CBW survey, 31% of localities reported used their UTCA to *evaluate potential impacts of tree canopy losses or gains*. The UTCA could also be used to assess possible impacts of natural catastrophes that diminish UTC, such as major storms or outbreaks of invasive pests.

A UTCA can also be used in a more specialized way to *monitor compliance with policies or regulation*. One respondent to the Virginia survey indicated the UTCA was being used to "follow up on required landscape buffers that have deteriorated over time", thereby monitoring compliance with local or state regulations. Periodic reassessments can also be used to document increases in UTC as a means of addressing environmental regulation requirements on stormwater or air quality. Because of the ecological function of UTC, including reducing stormwater runoff, sequential UTCAs could be used to prove UTC enhancement in areas prioritized to reduce stormwater runoff as a compliance measure for the Clean Water Act of the U.S. Environmental Protection Agency (EPA) (Nowak 2006). Furthermore, strategically planted urban trees can count toward EPA's Clean Air requirements through voluntary and emerging measures of State Implementation Plans (SIPs) (U.S. Environmental Protection Agency 2004). While 29% of CBW survey respondents noted that their locality used its UTCA to *demonstrate compliance with stormwater management goals or requirements (e.g., Municipal Separate Storm Sewer System (MS4) permits, Watershed Implementation Plans)*, only 2% said it was being used to *demonstrate compliance with air quality management goals or requirements (e.g. SIPs)*. This may be because localities are not currently under scrutiny for their air quality or because using trees in SIPs is an evolving air quality compliance strategy.

CONCLUSIONS

To our knowledge, this is one of the first studies to investigate the actual awareness and use of UTCAs by local governments across a broad geographic region. We chose the CBW for our study because numerous UTCAs have been performed in the region since the CBP identified UTC as a key strategy for Bay restoration. While evaluating the CBP's progress on their goal of "120 communities with UTC expansion goals by 2020" was not within the scope of our study, we were able to systematically explore the prevalence of UTCAs and how they are being used in local urban forestry programs.

As of mid-2013, there existed 55 UTC assessments in the CBW, encompassing 101 towns, cities, or counties. Surprisingly, we found that one-third of the key respondents from localities where a UTCA had been performed were not even aware that the UTCA existed. This indicates an opportunity for outreach to those smaller localities where a UTCA exists but the data have not been shared or an effort to provide the necessary technical assistance has not been made.

Furthermore, we found that even in localities that were aware of their UTCA, actual use of the UTCA ranged from those localities not using it for any of the 17 potential activities, to those using it for all of them. We developed a conceptual model of general and specialized UTCA uses within the urban forest planning framework described by Miller (2007), with the most frequently reported uses also being the most general (unspecialized) uses. Responses indicated that UTCAs were being used with similar frequency at all stages of urban forest planning: 49% for UTC goal setting, 57% for UTC implementation strategies, and 49% for UTC monitoring and evaluation. Localities reporting a specialized use were also performing the general use within the same stage. While most CBW localities have been using their UTCA to at least some extent, it appears that overall localities tend to underutilize their UTCA.

This study has demonstrated that there is opportunity to enhance the utility of a UTCA based on our finding of limited awareness and limited use of the UTCA by CBW localities. In order to make the most effective investments in UTCAs as a planning and management tool, additional insight is needed into why some local governments use the UTCA more than others. Ultimately, continuing to increase overall awareness of both the existence and utility of a UTCA could pay important dividends and substantively improve the capacity of local urban forestry programs.

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APPENDIX 1. Description of 101 localities in the Chesapeake Bay watershed for which an urban tree canopy assessment (UTCA) had been performed as of mid-2013. Note that the locality may be a sub-unit within the geographic scope of a larger UTCA. Population and land area from US Census Bureau (n.d.).

State	Locality Name	Locality Type	Population	Land Area (km^2)	Geographic Scope of UTCA
DC	Washington	capital district	617,996	159	District of Columbia
DE	Georgetown	town	6,422	11	Town of Georgetown
DE	Harrington	city	3,562	5	City of Harrington
DE	Laurel	town	3,708	4	Town of Laurel
DE	Middletown	town	18,871	17	Town of Middletown
DE	Seaford	city	6,928	9	City of Seaford
MD	Aberdeen	city	14,959	18	Harford County
MD	Annapolis	city	38,394	19	City of Annapolis
MD	Anne Arundel	county	537,656	1,077	Anne Arundel County
MD	Baltimore	independent city	620,961	210	Baltimore City
MD	Baltimore	county	805,029	1,551	Baltimore County
MD	Bel Air	town	10,120	8	Harford County
MD	Berwyn Heights	town	3,123	2	Prince George's County
MD	Bladensburg	town	9,148	3	Prince George's County
MD	Bowie	city	54,727	48	City of Bowie
MD	Brentwood	town	3,046	1	Prince George's County
MD	Brunswick	city	5,870	8	City of Brunswick
MD	Capitol Heights	town	4,337	2	Prince George's County
MD	Chestertown	town	5,252	7	Chestertown
MD	Cheverly	town	6,173	3	Prince George's County
MD	Chevy Chase	town	2,824	1	Montgomery County
MD	College Park	city	30,413	15	Prince George's County
MD	Cumberland	city	20,859	26	City of Cumberland
MD	District Heights	city	5,837	2	Prince George's County
MD	Frederick	city	65,239	57	City of Frederick
MD	Gaithersburg	city	59,933	26	Montgomery County
MD	Glenarden	city	6,000	3	Prince George's County
MD	Greenbelt	city	23,068	16	City of Greenbelt
MD	Hagerstown	city	39,890	31	City of Hagerstown
MD	Harford	county	243,085	1,140	Harford County
MD	Havre de Grace	city	12,952	14	Harford County
MD	Howard	county	287,085	653	Howard County
MD	Calvert	county	88,944	557	Calvert County

State	Locality Name	Locality Type	Population	Land Area (km^2)	Geographic Scope of UTCA
MD	Hyattsville	city	17,557	7	City of Hyattsville
MD	Laurel	city	25,115	11	Prince George's County
MD	Montgomery	county	971,777	1285	Montgomery County
MD	Mount Rainier	city	8,080	2	Prince George's County
MD	New Carrollton	city	12,135	4	Prince George's County
MD	Poolesville	town	4,883	10	Montgomery County
MD	Prince George's	county	863,420	1257	Prince George's County
MD	Riverdale Park	town	6,956	4	Prince George's County
MD	Rockville	city	61,209	35	City of Rockville
MD	Seat Pleasant	city	4,542	2	Prince George's County
MD	Takoma Park	city	16,715	5	City of Takoma Park
MD	University Park	town	2,548	1	Prince George's County
PA	Akron	borough	4,046	3	Lancaster County
PA	Archbald	borough	6,984	44	Scranton Metro Area
PA	Blakely	borough	6,564	10	Scranton Metro Area
PA	Clarks Summit	borough	5,116	4	Abingtons Suburb Area
PA	Columbia	borough	10,400	6	Columbia Borough
PA	Denver	borough	3,332	3	Lancaster County
PA	Dickson	borough	6,070	12	Scranton Metro Area
PA	Dunmore	borough	14,057	23	Scranton Metro Area
PA	East Petersburg	borough	4,450	3	Lancaster County
PA	Elizabethtown	borough	11,887	7	Lancaster County
PA	Ephrata	borough	13,394	4	Lancaster County
PA	Jessup	borough	4,676	17	Scranton Metro Area
PA	Lancaster	city	59,322	19	City of Lancaster
PA	Lancaster	county	519,445	2,458	Lancaster County
PA	Lititz	borough	9,029	6	Lancaster County
PA	Manheim	borough	4,858	4	Manheim Borough
PA	Marietta	borough	2,689	2	Lancaster County
PA	Millersville	borough	7,774	5	Lancaster County
PA	Moosic	borough	5,719	17	Scranton Metro Area
PA	Mount Joy	borough	6,765	6	Lancaster County

State	Locality Name	Locality Type	Population	Land Area (km^2)	Geographic Scope of UTCA
PA	New Holland	borough	5,092	5	Lancaster County
PA	Old Forge	borough	8,313	9	Scranton Metro Area
PA	Olyphant	borough	5,151	14	Scranton Metro Area
PA	Scranton	city	76,089	65	Scranton Metro Area
PA	State College	borough	42,034	12	State College Borough
PA	Strasburg	borough	2,800	3	Lancaster County
PA	Taylor	borough	6,263	13	Scranton Metro Area
PA	Throop	borough	4,088	13	Scranton Metro Area
VA	Arlington	county	207,627	67	Arlington County
VA	Ashland	town	7,225	19	Town of Ashland
VA	Charlottesville	independent city	43,475	27	City of Charlottesville
VA	Chesapeake	independent city	222,209	907	City of Chesapeake
VA	Fairfax	county	1,081,726	1,023	Fairfax County
VA	Fredericksburg	independent city	24,286	27	City of Fredericksburg
VA	Front Royal	town	14,440	25	Town of Front Royal
VA	Herndon	town	23,292	11	Fairfax County
VA	Leesburg	town	42,616	32	Town of Leesburg
VA	Lexington	independent city	7,042	6	City of Lexington
VA	Luray	town	4,895	12	Town of Luray
VA	Lynchburg	independent city	75,568	127	City of Lynchburg
VA	Manassas	independent city	37,821	26	City of Manassas
VA	Newport News	independent city	180,719	180	City of Newport News
VA	Norfolk	independent city	242,803	139	City of Norfolk
VA	Portsmouth	independent city	95,535	90	City of Portsmouth
VA	Purcellville	town	7,727	8	Town of Purcellville
VA	Richmond	independent city	204,214	156	City of Richmond
VA	Vienna	town	15,687	12	Fairfax County
VA	Virginia Beach	independent city	437,994	642	City of Virginia Beach
VA	Waynesboro	independent city	21,006	40	City of Waynesboro
VA	Winchester	independent city	26,203	24	City of Winchester
VA	Woodstock	town	5,097	8	Town of Woodstock
WV	Berkeley	county	104,169	834	Berkeley County
WV	Charles Town	city	5,259	15	Jefferson County
WV	Jefferson	county	53,498	544	Jefferson County
WV	Martinsburg	city	17,227	17	Berkeley County
WV	Ranson	city	4,440	21	Jefferson County

APPENDIX 2. Description of urban forestry program capacity for 51 Chesapeake Bay localities that responded to a survey about their use of an urban tree canopy assessment (UTCA) performed for their jurisdiction. Data given as percent (and count) of respondents for all 51 localities.

Urban Forestry Program Capacity	% (Count)	
Staffing		
There is a multi-disciplinary team	**16%** (8)	
There are professional arborists or foresters on staff with regular professional development	**25%** (13)	
There are urban forestry staff, but they have no specialized training or professional credentials	**8%** (4)	
There are no urban forestry staff	**51%** (26)	
GIS Expertise		
There is a GIS expert in-house	**47%** (24)	
There is some GIS expertise in-house	**25%** (13)	
There is no GIS expertise in-house	**25%** (13)	
No response	**2%** (1)	
Funding		
There is adequate funding to sustain and maximize our urban forest and urban forest benefits	**16%** (8)	
There is only enough funding to support management of our current urban forest	**22%** (11)	
There is insufficient funding to support management of our current urban forest	**61%** (31)	
No Response	**2%** (1)	
Management Plan		
There is a comprehensive urban forest plan that has been accepted and is being implemented	**10%** (5)	
There is a comprehensive urban forest plan pending acceptance and implementation	**10%** (5)	
There is an existing urban forest plan but it is limited in scope and implementation	**27%** (14)	
There is no urban forest management plan	**53%** (27)	
Inventory		
There is a current inventory of street trees and other public trees	**4%** (2)	
There is a current inventory of street trees only	**14%** (7)	
There is an outdated inventory	**29%** (15)	
No tree inventory exists	**53%** (27)	
The locality has…	**Yes**	**No**
…a municipal tree planting program	**59%** (30)	**41%** (21)
…a tree commission	**71%** (36)	**29%** (15)
…someone who has attended training or a workshop on UTC assessment	**27%** (14)	**73%** (37)