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TÍTULO:
Determination of Tree Mortality Rate in Public Urban Areas at Early Stages After Planting

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Abstract

Measuring urban tree mortality rates during the first several years after planting is a growing field of study for urban forestry practitioners. Mortality rates for timber species in forest stands have been measured extensively over time, but stand level mortality research in urban forests has remained localized and isolated until the 1990's. By concentrating research in this area, practitioners will be in a better position to understand the best practices for urban forest management in response to different conditions and methods. The city of Baltimore, in Maryland, USA, has been collecting tree planting records since 2009, which illustrate a variety of planting and maintenance methods performed by several different organizations. In the present study, a sample of planting sites was chosen from the records, representing the two major site types and a selection of the major planting and maintenance procedures. Mortality rates were determined for each site and compared with other planting sites. This study has led to the identification of factors that affected the early survival rate of newly planted trees in the subject sites. More importantly, it has motivated an examination of the methodology for a quantitative assessment of tree mortality rate. As a topic for further study beyond the scope of this thesis, methods are currently being developed to perform this study on a wider scale. This study is relevant to Mediterranean forestry because the methodology presented here can be adapted to analyze urban forest plantings in Mediterranean cities.

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Introduction

Changing scope and definition of urban forestry

The Society of American Foresters defines urban forestry as “the art, science, and technology of managing trees and forest resources in and around urban community ecosystems for the physiological, sociological, economic, and aesthetic benefits trees provide society” (Helms, 1998). The British National Urban Forestry Unit in 1999 published that the urban forest “collectively describes all trees and woods in an urban area: in parks, private gardens, streets, around factories, offices, hospitals and schools, on wasteland and in existing woodlands” (NUFU, 1999). However, the scope of the practice of urban forestry and the components included in the urban forest vary temporally by country and region. The practice of urban forestry has separate historical origins in United States and Europe, with different local definitions which have each evolved and combined over time in response to sharing of practices and ideas between regions. The harmonization of definitions has been challenged by differing literal translations of the terms into other languages (Konijnendijk et al., 2006). The three components required to describe the scope of urban forestry are (a) the vegetation included, (b) the costs and benefits generated, and (c) the types of setting and locations being included (Randrup et al., 2005).

In the United States, professional urban forestry began in the late 1800s with the appointment of municipal level forestry professionals in several northeastern states (Williams, 1989; Ricard, 2005). These professionals practiced what is now considered part of urban forestry but under different titles, such as city arborist, tree warden, shade tree commissioner, or municipal forester (Harris, 2004). Throughout early and middle 20th century, the main focus of urban forestry practice was on shade tree planting and management programs mainly along streets and parks and coincided with the beginning of the field of arboriculture. In the 1960s and 1970s, major academic conferences and university faculty members in the United States and Canada renewed an interest in urban forestry, expanding the scope to include the physiological, sociological, and economic benefits to urban society (Konijnendijk, 2006). The U.S. Cooperative Forestry Act of 1978 established legislation that enabled the federal U.S. Forest Service to include the study and participation in urban forestry practices as part of its responsibilities (Miller, 1997). By the 1990s, the accumulated academic and government involvement in urban forestry led to its rapid expansion in cities across the United States and the province of Ontario, Canada (Konijnendijk, 2006). The field of urban forestry in North America has changed and grown to become multidisciplinary and encompassing of all trees and the full forest ecosystem, in and around cities and towns, as well as its costs and benefits to society.

In Europe there is a centuries-long history of town forestry, where cities own and manage an adjacent or nearby area of forest. There is also a long history of well-maintained parks and gardens associated with the nobility and the wealthy, which were not usually available to the general public (Konijnendijk, 2006). Public managed greenspaces started becoming common during 19th century industrialization as populations migrated to the cities, but there was segmented management of park vegetation, street trees, woodlands, and gardens. Comprehensive greenspace planning and management approaches emerged in the 1970s in connection with the fields of urban and landscape ecology (Werquin et al., 2005; Konijnendijk, 2006). The term and concept of 'urban forestry' started spreading into UK and Netherlands from international conferences in the 1980s, and has been met with resistance from traditional foresters as well as the professionals that already take care of parks and gardening (Johnston, 1997; Konijnendijk, 2003). Gradual acceptance and professional networks have spread since the 1990s (Konijnendijk, 2006), and COST Action E12 Urban Forests and Trees was conducted by the European Union between 1997 and 2002 (Konijnendijk et al., 2005A). As the concept has been adapted to the specific conditions in different European countries, a variety of approaches and definitions exist today (Konijnendijk, 2006).

Urban forestry is an interdisciplinary field which involves many different professionals. While an arborist is focused on individual trees, the urban forester is concerned with the whole collection of trees and forest ecosystems in and around the city. From an urban forester perspective, the population of trees in a neighborhood is treated as a sparse stand of trees for the purposes of forest planning and management. The mosaic of different forest components in and around an urban area aggregates to a significant and large forest with large production potential. Production of traditional forestry timber products is diminished in exchange for other forest outputs such as specialty mixed-species timber, food products, biofuels, compost, mulch, environmental services, social benefits, and other non-wood forest products.

Relevance to Urban Forestry in the Mediterranean

While this study is sited in a northeast American city with a temperate climate, it is relevant to Mediterranean forestry because urban forests are also existent and actively managed in Mediterranean cities. For example, the city limits of Barcelona have an estimated population of over 1.4 million trees, 799,492 are in natural forests, 212,437 are in parks and gardens, and 407,934 are spread throughout the other city land uses (Chaparro & Terradas, 2009). This present study can serve as an example of quantitative investigation of tree mortality in a city with several coexisting planting organizations and variable factors. In December 2014 the mayor of Madrid, Spain invited city residents to volunteer to plant trees in the public park named “el Bosque de los Ciudadanos del Parque Forestal de Valdebebas” (El Mundo 2014). Using planting labor from volunteers is a possible cost saving complement to professional tree planting workers. Performing a mortality study to compare the two types of labor is one step in performing a cost-benefit analysis between the methods.

The problems and difficulties encountered in this study can serve as lessons about potential issues that need to be considered when planning similar local studies. The tree surveying method and location measurement utilized in this study demonstrate a low-cost approach to collecting data using widely available modern tools and equipment that many government agencies and universities may already own and use. During the literature review process for this project, it was difficult to find documents published in English detailing European or Mediterranean methods of measuring mortality in trees planted throughout cities. While large cities like Barcelona have expansive GIS datasets used for tracking and monitoring their urban forest (Ajuntament de Barcelona, 2011), other cities may have yet to implement the use of GIS for this purpose. This project serves as an example of one possible way to use GIS software to collect and manage the data necessary for performing a tree mortality study in a city.

Benefits of Trees in Urban Forests

The main purpose served by forests in urban environments is for other than wood production, namely for ecological, social, as well as economic reasons. It is becoming apparent that the development of urban forests is tied to the rise in the average standard of living and the demand from modern societies for a cleaner environment. Ecological benefits provided by trees in cities include carbon sequestration (Nowak, 1993; Nowak & Crane, 2002), removal of pollution from the atmosphere (Yang et al., 2005; Nowak et al., 2006), storm-water interception and absorption (McPherson et al., 2005), absorption of toxic pollutants in the soil and groundwater (Jensen et al., 2009), and wildlife habitat (Livinston et al., 2003). Social benefits include positive effects on the health and wellbeing of humans (Abraham et al., 2009), and mitigation of the urban heat island effect (Akbari et al., 2001). Economic benefits are derived from the social and ecological benefits of the trees in the city, for example improving the energy efficiency of adjacent buildings (Akbari 2002). Urban forests are sometimes utilized for specialized or niche industries, such as maple sap tapping, mushroom cultivation, shade for herbaceous plant production, composting, etc. A current benefit related to climate change is the potential to test and naturalize tree species from warmer climate regions, since cities experience warmer temperatures than their rural surroundings due to the urban heat island effect.

Costs of Trees in Urban Forests

Costs of trees in urban areas are also numerous, and must be considered when determining the trade-off for the benefits. The most obvious and direct cost to the forest manager is that of purchasing and delivering the tree, preparing the planting site, installing the tree, installing protective devices, maintaining the tree, and finally removing the tree when necessary. The direct monetary costs per tree can be much higher in urban forestry than in traditional forestry. Pauleit et. al 2002 conducted a survey of European tree establishment practices in towns and cities in 1999 - 2001, asking urban forest managers in different European countries to indicate average planting and establishment costs per street tree, including labor and materials. Of the 11 countries that were surveyed, 5 countries reported average costs per tree of over 1,000 Euro, and 3 countries reported costs per tree between 250 - 1,000 Euro (Pauleit et. al 2002). The wide variety in average costs reflects differences in tree quality, site preparations, and labor costs.

Trees planted in public urban areas often require the purchase of larger size trees, soil amendments may be necessary in disturbed soils. In cases where individual planting sites may be distributed across blocks or neighborhoods, planting holes must be individually dug and prepared, resulting in added logistics and labor. Protective devices are frequently installed to prevent damage to the trees from human traffic, maintenance tools, machinery, and deer. Examples of protective devices can be seen in Figure 1, and include items like stakes, fencing, and trunk protectors. Some of these accessories serve multiple purposes, but still result in restricting potential damaging contact.

The indirect costs of trees on the urban infrastructure include damage to sidewalks, utility lines, street lights, signs, buildings, and other structures. The failure of large trees in urban areas may also result in property damage, human injury, or loss of life, which all inevitably result in monetary expenses. Social costs, also interpreted as negative effects on urban residents, include increased levels of pollen in urban areas that prompt allergies in many people and obstructed visibility, which may be linked to crime or crashes. The presence of hazardous trees in densely populated areas could lead to loss of life, injury, or property damage and the attraction of unwanted wildlife such as deer or large populations of birds and pests. Environmental costs include the release of volatile organic compounds (VOCs) and the formation of ozone close to the ground level (Konijnendijk et. al 2005B).

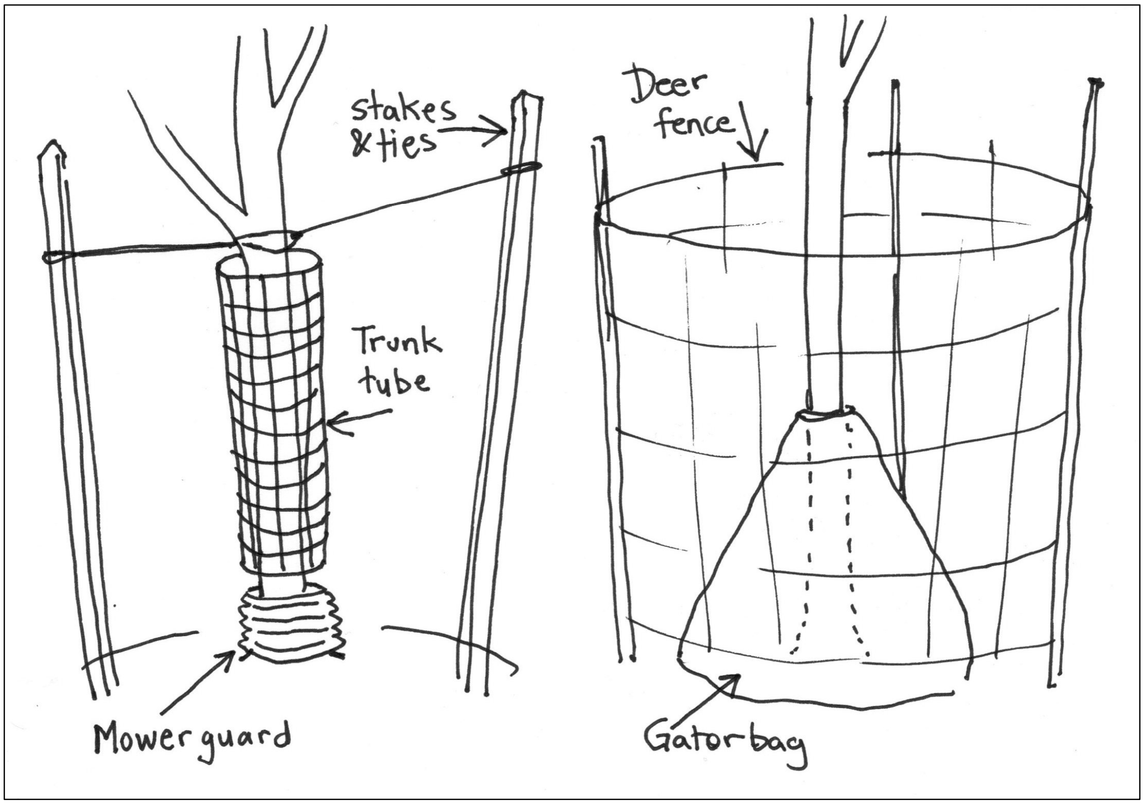

Figure 1: Examples of tree protective devices

Challenges to tree survival in urban areas

Urban trees face many of the same challenges as in natural forests, as well as many harsh and variable environmental conditions related to their proximity to urban areas and human activities. In certain types of urban planting locations tree lifespans are much shorter than in natural forest settings (Skiera & Moll 1992). Soil space is limited in certain types of planting sites, such as planting spaces surrounded by or adjacent to impervious surfaces. There are problems with soil compaction in trafficked sites, water availability problems, and inadequate space for the roots to grow and reach nutrients (Day & Bassuck 1994). The higher concentration of air and soil pollution in cities is also a source of stress for the trees (Konijnendijk et. al 2005B), in addition to applications of deicing salt or chemicals in cities experiencing snow and ice. Human activities can lead to tree damage, and ongoing construction and development in cities threatens otherwise healthy trees with removal (Nowak et. al 2010). Trees in challenging conditions depend on maintenance and watering especially in the first years after planting (Nowak et al 1990).

During the first years after planting trees have a higher risk of dying, until their root systems become established and the trees grow larger (Lu et al. 2010; Roman and Scatena 2011).

Trees planted in cities experience higher mortality rates at a young age, which decrease and stabilize as the tree reaches maturity, and then increase again as the trees become older. This mortality trend resembles that of natural forests and managed forest stands, except that urban trees tend to have shorter lifespans. Urban environments require tree stock for planting to be larger than in traditional forestry applications, exceeding specific height and caliper criteria, thus resulting in a higher purchasing and planting cost per tree. It is important for these trees to survive until maturity because that is when they provide the majority of their ecosystem services (EPA 2004; Lu et al. 2010).

Tree Planting Performance and Mortality

The performance of an urban tree planting program can be measured in several different ways. Performance measures include the count of trees planted in a time period, the survival rates of those trees over time, and the calculation of the benefits and costs generated by those trees. The count of trees planted in a time period is the simplest and most common measure, but it reflects only the starting population. Measuring the number of those trees over time makes it possible to calculate mortality rates to estimate future populations and to compare the success of different materials and methods. Estimating future populations is necessary for the calculation of the environmental benefits and costs using models such as UFORE, also known as i-Tree. It is not possible to estimate future environmental benefits of a planting without being able to know the expected survival rates for the trees planted.

In 2004 the US EPA published a study compiling the mortality rates found in nine individual studies which examined the percent mortality of young urban trees. The studies focused on different sites, such as streets, parks, school grounds, and woodlands. Some of the studies focused on planted trees only, while others measured all trees present at the sample sites. The compiled average annual mortality rates were mostly between 3-11%, with two instances reporting 19-20%. (US EPA, 2004).

Lu et al. (2010) presented a mortality assessment of 45,000 street trees in New York City two years after planting and found the mortality to be 8.7%, thus indicating a 4.4% annual mortality rate. Further investigation into the first nine years after planting revealed that mortality rates are markedly higher in the first few years, then reduce and stabilize after the establishment phase (Lu et al. 2010). The establishment phase can be defined as the first several years after planting. Once trees reached 7-9 years, the total mortality difference between age classes became negligible. Other factors that were shown to significantly affect mortality were land use type, species, stewardship levels, and site design conditions (Lu et al. 2010).

Roman and Scatena (2011) presented a larger compilation of 16 mortality studies, showing that a wide variety of methods were being used in the different studies. When the individual studies are compared, the length and interval of the analysis periods are all different from each other. The shortest intervals are 0.25 and 1 year, and longest intervals are over 60 years. Some of the studies also include older trees. The types of sites being included are also inconsistent, with various combinations including some or all of street trees, park trees, woodlands, or other public trees. Converting the mortality rates to average annual mortality yielded a range of 1-20%, with an outlier of 65% (Roman and Scatena, 2011).

<u>The Rise of the Tree Planting Programs in American Cities</u>

Over the last twenty years many cities across the United States have embarked on massive tree planting campaigns with lofty goals, spending large amounts of capital to plant trees with the general goal to increase tree populations or canopy coverage in and around cities for the environmental benefits they provide (Pincetl et. al 2012). For example New York City's program Million Trees NYC is currently in the process of planting one million trees throughout the city over ten years. Some other well-known tree planting programs include Los Angeles Million Trees, Casey Trees Washington DC, Chicago Forestry Bureau, TreeBaltimore, TreePhilly (Philadelphia), TreePittsburgh, and the list goes on to currently include many large and medium sized cities. See Appendix 1 for an expanded list of tree planting programs and references. These planting programs use a combination of approaches and organizations to perform the plantings, ranging from paying professional planting crews to relying on organized volunteer labor with subsidized materials.

While in many European cities it is primarily the responsibility of the municipal agencies to plant the trees, American municipalities' perform tree plantings as possible within their allocated budgets, then support non-governmental organizations (NGOs) and volunteer groups to perform additional plantings and maintenance activities (Pincetl et. al 2012). The NGOs and volunteer groups receive grant funding, subsidies, or alternate funding to perform these activities. Importantly, trees planted on public property become the property of the government, even those planted by the NGOs or volunteers, meaning that maintenance beyond the establishment phase is the ultimate responsibility of the government.

In European and Mediterranean cities, the majority of tree related work in urban areas has been historically performed by government agencies such as park and garden departments, or streetway/paths departments (Konijnendijk 2006). As the field of urban forestry has evolved to include these urban trees along with woodland trees and all vegetation in the city, a renewed interest has been placed on their tree planting and maintenance activities. There is evidence of large scale tree planting activities in cities across Spain and France (Appendix 1 contains a list of internet and media references), however it was difficult to find websites detailing centrally coordinated efforts in a city. There is also evidence of using volunteer labor to perform tree plantings on public property, with recent examples from Madrid and Murcia, Spain in Appendix 1.

Baltimore City Forestry Division

The City of Baltimore's Forestry Division is part of the Department of Recreation and Parks. The Forestry Division is primarily responsible for inspecting, maintaining, and removing dead or dying trees on public property along city streets and in parks. The streetside responsibilities apply only to the city owned portion of land, which includes the sidewalk or sometimes a portion of land on either side of the street. While the Forestry Division does plant a limited number of trees each year, the majority of trees are planted by a wide variety of planting organizations using different methods. The Forestry Division reviews planting plans and grants permission to organizations or volunteers who wish to plant within its jurisdiction, but requires organizations to assume maintenance responsibilities for the first two years after planting.

In Baltimore city, the trees felled by the Forestry Division have been sold, traded, or made available for a variety of purposes. Branches, small diameter wood, or other poor quality material is converted into woodchips, mulch, compost, or used as biofuel. The felled timber deemed of useable quality is sent to the Forestry Division's sorting facility, where logs are separated and sold to local mills or woodworkers. Some non-wood forest products derived from the local urban forest include maple sap tapping, mushroom cultivation, shade tolerant plant production, fruit production, and foraged edible wild plants.

TreeBaltimore Program

TreeBaltimore, a program operated by the municipal Forestry Division, aims to coordinate activities between all planting organizations in the city. TreeBaltimore was created in 2007 by Mayor Martin O'Malley to engage forestry stakeholders with the goal to increase the city's tree canopy. The goal set in conjunction with this program was to achieve a 40% tree canopy cover over the land of the city by the year 2037, 30 years after the start of the program. The measurements taken by a study commissioned by the US Forest Service determined that in 2007, only 27.4% of all land in the city was covered by tree canopy (O'Neil-Dunne, 2009). Further work was performed to determine how to prioritize the location planting activities across the city, by using a weighted ranking system considering a number of environmental and socioeconomic factors (Morgan & Locke, 2011).

Objectives

Citywide planting programs such as TreeBaltimore aim to achieve certain canopy goals or maintain a certain population of trees. The future environmental and social benefits are the primary reason driving current planting programs. Understanding the mortality rates of these urban plantings is crucial to determining the quantity of initial trees required to meet specific mature target populations or canopy cover. Determining which factors affect mortality in the first years after planting also allows cost-benefit analysis of the alternate planting and maintenance methods. On these bases, the specific objectives of this research were to:

- Compile and describe the planting records collected by the TreeBaltimore program.
- Determine the mortality rates for a sample of trees planted on public property, during the first years after planting.
- Determine if there is a difference in mortality rates for trees planted by different planting organizations.
- Determine if there is a difference in mortality rates for trees planted in different site types.
- Propose a locally viable method by which to record tree plantings and monitor their survival performance.

Materials and Methods

Study Location: City of Baltimore, Maryland, USA

Criteria for the selection of the study location included: (a) the existence of a current tree planting program, (b) the existence of planting records from several planting organizations, (c) the existence of various planting site types, (d) the existence of various planting and maintenance techniques in practice, (e) the willingness of the city's forestry agency to collaborate and fund parts of the research, and (f) the lack of existing monitoring and assessment at the location.

Baltimore, Maryland is a city located in the MidAtlantic region of the east coast of the United States of America, along the northwestern banks of the Chesapeake Bay. In 2010 Baltimore had a population of 620,961 as measured by the national Census, and latest estimates place the population at 622,793 as of 1 July, 2014 (US Census Bureau, 2015). Baltimore has a total area of 23,840.5 hectares (92.05 square miles) within its city limits, but water occupies 2,877.5 hectares (11.11 square miles), leaving 20,963.4 hectares (80.94 square miles) of land area. The average population density per square mile of land area is 7,671.5 (US Census Bureau, 2010).

Historical settlement and development patterns in the city area have resulted in approximately 75% of the soils being disturbed and altered, with the remaining 25% of relatively undisturbed soils located in the city's parks, forests, and steep terrain unfavorable to development (Levin & Griffin, 1998). The city straddles two physiographic provinces, with the dividing line bisecting the city along a northeast-southwest line known as the Fall line. To the north and west of the Fall line is the Piedmont plateau with underlying old igneous and metamorphic rock, and to the south and east of the Fall line is the Atlantic Coastal plain with underlying younger poorly consolidated sediment (Levin & Griffin, 1998).

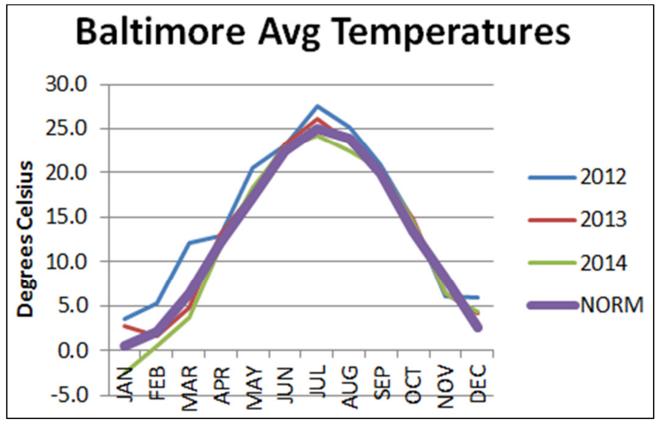

Figure 2: Average Temperature in Baltimore

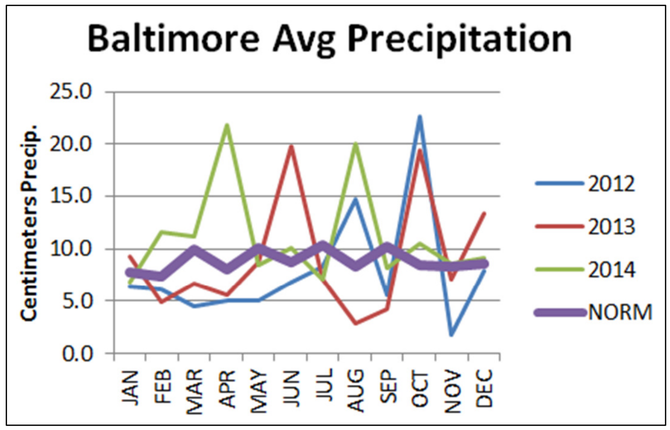

Figure 3: Average Precipitation in Baltimore

Baltimore has a humid temperate climate with an average temperature of 25 degrees celsius in July and 0.5 degrees celsius in January (Figure 2). The precipitation averages between 7.4 - 10.3 cm per month, with an annual average of 106.4 cm (Figure 3). Averages are calculated over the period of 1881-2010 (National Weather Service, 2015).

<u>Baltimore Tree Planting Records</u>

TreeBaltimore functions as the coordinating program for all tree planting activity in the city, so it is responsible for reporting total tree planting numbers to other government agencies and NGOs. At the end of every planting season, TreeBaltimore requests planting information from each of the organizations involved in tree plantings within the city's public property. This information describes the types of trees planted, the location of the planting, and the organizations involved in the planting and maintenance of the trees. Record keeping began prior to the launch of TreeBaltimore program in 2007, however subsequent loss of all records occurred because of changes in staff and computer equipment, and much of the historic data was never recovered. Current records reflect all planting information collected since 2009.

While efforts were made to collect planting data from each planting organization after every planting season, there were no repercussions for failing to comply. Records are missing from several organizations, therefore the entire record only represents a portion of total tree planting activity since 2009. TreeBaltimore's lack of authority over other government agencies outside the Forestry Division has proven a challenge to collecting government tree planting data. While the government agency plantings are often recorded in detailed planting plans, they are not compiled into reports, and are rarely reported to TreeBaltimore, thus requiring TreeBaltimore staff time to pursue and acquire these documents. The NGO plantings face a different challenge, because while the funding they receive requires them to report numbers of trees to the funding sources, record keeping methods vary and the quality of the data is questionable. TreeBaltimore staff have worked closely with the NGOs to develop higher quality record keeping methods that can still be achieved with their limited budgets. As a result of ongoing efforts, the quality and quantity of tree planting data has improved since 2012, but still needs to improve further.

The standard tree planting reporting forms, as well as other planting reporting methods encountered during this study are presented in Appendix 2.

Site Types

In the records of the TreeBaltimore program, most tree plantings have occurred in one of three site types: (a) streets, (b) parks, and (c) school grounds. Street trees are planted adjacent to streets or sidewalks in highly disturbed ground, often in small patches of open ground surrounded by impervious surfaces, or in medians (see figures 4 and 5). Park plantings are are located in publicly accessible parks and green spaces with large proportions of pervious ground cover, and trees are usually planted in groups or spread around walkways (see figures 6 and 7). School plantings are located in the green spaces on school grounds, and trees are also usually planted in groups or spread around walkways (see figures 8 and 9). In this study the park and school plantings are combined due to the similarities in site conditions. Sidewalk, street side, or median trees are combined into a single category for street trees. Additional site types represent a very small proportion of the plantings in the TreeBaltimore records; these include cemeteries, commercial property, industrial property, or other private property.

Figure 4: Street tree planting, in a median between opposing directions of traffic.

Figure 5: Street tree planting, in sidewalk planting spaces.

Figure 6: Tree planting at a Park site, in a field next to woodlands and a river.

Figure 7: Tree planting at a Park site, close to walkways.

Figure 8: Planting at a School site, between the school's athletic fields and existing woodlands.

Figure 9: Planting at a School site, in green spaces next to walkways.

Table 1 shows the total reported trees planted in the main site types, broken down by year. Street tree planting has been consistently performed at varying levels for decades, however records do not exist before 2009. Park and school plantings have increased dramatically as a result of the TreeBaltimore program.

Trees Planted	**Year**						
Place Type	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**	**Grand Total**
Street	1918	1500	1627	624	1308	1840	8817
Park/School	3245	4414	2006	617	242	104	10628
Grand Total	**5163**	**5914**	**3633**	**1241**	**1550**	**1944**	**19445**

Table 1: TreeBaltimore total reported trees planted, separated by site type.

Planting Organizations

There are several large organizations and dozens of smaller organizations that participate in planting trees on public property throughout the city. The planting organizations can be divided into two general categories: government agencies and non-governmental organizations (NGOs). Several government agencies perform tree plantings in the city, like the the municipal Forestry Division, the parks Capital Improvements Division, the municipal Department of Public Works, and the municipal and state Department of Transportation. The NGOs are non-profit organizations that focus on providing benefits to city residents, and perform tree plantings as one part of their portfolio of activities. NGOs receive funds to perform activities that benefit society, funded by a combination of sources that include grants, private companies, philanthropists, and the government. Examples of tree planting NGOs include neighborhood associations, park associations, watershed associations, and locally specific environmental organizations.

There is a major difference in the planting and establishment methods used by NGOs and by the government agencies. Government agencies usually hire professional tree planting contractors to perform the plantings while NGOs have staff that coordinate groups of volunteers to perform the plantings. Government agencies purchase trees that are larger than the trees planted by NGOs, and often require machines to move or place in the ground. Professional contractors use specialized tools, machinery, and professional manual labor to perform the plantings. Site preparations often include soil amendments and tree protective devices per the specifications in their contract. Trees come with a two year replacement warranty from the contractor if the tree dies during that time, but despite this the contractors often perform no regular maintenance or waterings of the trees.

NGOs have staff that pursue funds, plan tree plantings, perform the plantings, and then coordinate their maintenance. Planning of the planting involves approval from the local neighborhood residents as well as the government. To perform the plantings, NGO staff arrange for delivery of materials and tools, then at scheduled events NGO staff instruct and lead a group of volunteers in planting a group of trees. Trees are delivered by truck and sometimes placed with machines. Trees are often smaller than trees planted by government agencies, since the final part of the planting work is performed by hand by volunteers with basic tools. Soil amendment and preparation is not usually as extensive as in contractor plantings, however protection devices are commonly installed. Maintenance of two years after planting is common agreement with the municipality, which includes watering, pruning, repairs, and potential replacement. Maintenance activities are also performed in staff and volunteer capacities. Table 2 shows total reported trees planted, separated by organization and year planted.

Trees Planted Reported	**Year**						
Organization Type	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**	**Grand Total**
NGO	4199	4964	2236	650	343	93	12485
Govt Agency	986	981	1424	515	1265	1851	7022
Grand Total	**5185**	**5945**	**3660**	**1165**	**1608**	**1944**	**19507**

Table 2: Total reported trees planted, separated by organization type and year

The majority of NGO plantings are reported by citywide environmental organizations that specialize in organizing and leading volunteer labor. The two most prolific citywide organizations are Blue Water Baltimore (BWB), and Parks & People Foundation (PPF). Table 3 compares the quantities of trees planted by the main organizations. Other plantings not performed by the main organizations are included in the 'NGO Other' and 'Govt Agency Other' category. The planting data in the records is incomplete before 2012, except for the Forestry Division, which has consistent records back to the beginning of collection.

The site type that the different organizations choose to plant in also differs, as seen in Table 4. The Forestry division is seen to plant almost exclusively street trees, while other government agencies plant in the parks. The main NGOs plant most of their trees in the park and school sites, but still have street tree plantings.

Trees Planted	Year						
Organization Type	2014	2013	2012	2011	2010	2009	Grand Total
NGO PPF	2098	1853	645		268		4864
NGO BWB	1355	1426	1431	503			4715
NGO Other	746	1685	160	147	75	93	2906
Govt Agency Forestry	700	637	1245	477	1243	1786	6088
Govt Agency Other	286	344	179	38	22	65	934
Grand Total	**5185**	**5945**	**3660**	**1165**	**1608**	**1944**	**19507**

Table 3: Total reported trees planted, separated by organization subtype.

Trees Planted	Year			
Site Type	2014	2013	2012	Grand Total
Street	**1918**	**1479**	**1626**	**5023**
NGO PPF	497	142	306	945
NGO BWB	208	104		312
NGO Other	415	562	75	1052
Govt Agency Forestry	700	599	1245	2544
Govt Agency Other	98	72		170
Park/School	**3245**	**4408**	**2006**	**9659**
NGO PPF	1590	1696	339	3625
NGO BWB	1147	1322	1431	3900
NGO Other	320	1080	57	1457
Govt Agency Forestry		38		38
Govt Agency Other	188	272	179	639
Grand Total	**5163**	**5887**	**3632**	**14682**

Table 4: Total reported trees planted, separated by site type and organization subtype

Sampling Design

A cluster sampling method was chosen due to circumstances explained in the next paragraphs. Forty-six (46) planting sites were randomly selected from planting records dated 2013 and 2012, and all trees were surveyed at each of the selected sites. The group sites were all in parks, schools, and medians. In order to represent urban street trees, the whole neighborhood of Reservoir Hill was chosen as the 47th site because its records were the most complete at the time of this study. It had over 500 trees planted throughout the neighborhood between 2009 - 2014, and the planting organizations were able to assist in determining specific location of trees reported without unique locations. The resulting survey of each site was then compared to the original planting records for that site. The full list of sites is presented in Table 5 on the next page.

The preferred method to sample the trees would have been to stratify the planting records by site type and planting organization type for each year, then take a random sample of the trees in each category (Daniel, 2011). The site type categories could be (1) street trees, and (2) park or school plantings. The organization type categories could be (a) government agencies, and (b) NGOs (non-governmental organizations), or could be further stratified by major planting organization. To ensure adequate representation of the key site types and organization type categories, the sample sizes of each category could be proportional to their representation in the whole population.

Due to a problem with the existing planting records, the stratified sampling described above was not able to be performed. In the records the tree locations are defined by property address or place name. When a single tree is planted in front of a building, an address is sufficient. However most of the trees in the records did not have unique addresses for each tree. Plantings are often performed in groups that all share the same description of location. For example, if fifty trees were planted on the same day at a school campus, there would only be one address for the group of fifty trees, thus the individual trees are not uniquely identified. Even street trees were sometimes recorded as a group, specifying the quantity of trees planted in a neighborhood as part of one planting event. The reporting of tree plantings as groups instead of as individuals creates a problem for performing a random sample of trees in each category.

For groups of trees planted at schools and parks, in order to randomly sample the trees in each strata it would be necessary to survey all of the individual locations of each tree at every site. Additionally, since the group planting sites had not been surveyed at the time of planting, any removed trees would not have a location assigned to them. Performing full surveys of every site planted and reported in 2012 and 2013 was beyond the scope of this study.

List of Planting Sites Chosen for the Sample			
Site ID	**Row Labels**	**Site Type**	**Planting Org Type**
1	ACCE HS	School	NGO
2	Alexander Odum Park	Park	NGO
3	Armistead Garden EMS	School	NGO
4	Baltimore IT Academy	School	NGO
5	Belmont ES	School	NGO
6	Booker Washington MS	School	NGO
7	Cherry Hill Park	Park	NGO
8	Chinquapin Run Park - Midsection	Park	NGO
9	City College HS	School	NGO
10	Claremont HS	School	NGO
11	Clifton Park - Erdman	Park	NGO
12	Desoto Park	Park	NGO
13	Dr. Martin Luther King EMS	School	NGO
14	Druid Hill Park	Park	Gov Agency
15	Frederick Douglass HS	School	NGO
16	Green Street Academy	School	NGO
17	Guilford EMS	School	NGO
18	Gwynns Falls ES	School	NGO
19	Gwynns Falls Leakin Park - Winan's	Park	NGO
20	Gwynns Falls Trail - Carroll Area	Park	NGO
21	Hampden ES	School	NGO
22	Harford Heights EMS	School	NGO
23	Harlem Park ES	School	NGO
24	Herring Run Park - Armistead Gardens	Park	NGO
25	Herring Run Park - Brehms to Sinclair	Park	NGO
26	Hillen Rd Median	Street	Gov Agency
27	Hillen Triangle	Park	NGO
28	Jones Falls Trail	Park	Gov Agency
29	Lake Montebello	Park	NGO
30	Maritime Industries HS	School	NGO
31	Mary Ann Winterling ES	School	NGO
32	Matthew A Henson ES	School	NGO
33	MERVO	School	NGO
34	Moravia Park EMS	School	NGO
35	Morrell Park	Park	Gov Agency
36	NACA Academy / North Harford Park	Park	NGO
37	New Era Academy	School	NGO
38	Northeast MS	School	NGO
39	Paca and Atlantic Park	Park	NGO
40	REACH HS	School	NGO
41	Reginald F Lewis HS	School	NGO
42	Roosevelt Park	Park	NGO
43	Solo Gibbs Park	Park	NGO
44	Walter P. Carter EMS	School	NGO
45	Walther Ave Median	Street	NGO
46	Western HS	School	NGO
47	Reservoir Hill Neighborhood	All Types	Gov Agency & NGO

Table 5: List of Planting Sites Chosen for the Sample

For street tree plantings, a portion of the trees had been reported with unique addresses and another portion of the trees had been reported as groups planted throughout a neighborhood. Often times the street trees reported as groups overlapped those reported with individual addresses, introducing the potential for mistakes. In this case, a true random sample of all the street trees was complicated by not being able to determine the unique location of trees reported as groups in those areas. This complexity limited the possible options for sampling street trees. Treating a neighborhood unit as a group site allowed for the selection of a whole neighborhood in which to survey all street trees. Accurately sorting out the records for a neighborhood would require the assistance of the planting organizations that had performed those plantings. For these reasons a single neighborhood was chosen that had a robust planting record and support from the local planting organizations.

Equipment, tools, and software

For data management and analysis this project required the use of a Windows 7 PC computer with Microsoft Office 10, ESRI ArcGIS 10 software, and ESRI ArcGIS Online access. An iPad 3 with 3G data connection was used with the ESRI Collector application to collect data and measure locations. Basemap GIS data and aerial photography were provided by the municipal IT department and the Recreation and Parks department. Two tree identification field guides for native and planted trees in eastern United States were also used (Kershner 2008; Sibley 2009). A vehicle was used to travel to the sites, and a measuring caliper and tape measurer were kept on hand for good measure. All of the items used to perform this study were already owned and in use by the Baltimore City Forestry Division or other municipal agencies.

Site surveying methods

The main goals of surveying were to produce a map of each site showing the unique location of each tree, and to collect data about each tree in the map. Several successive plantings over subsequent years were found to occur at single sites, so it was necessary to distinguish between different phases of planting. The reports that TreeBaltimore had received did not contain sufficient information to be able to identify which trees belonged to which planting. Establishing contact with the planting organization was crucial to being able to successfully survey a site and identify which trees were part of which planting. Communications were established with staff at the following organizations: Blue Water Baltimore, Parks & People Foundation, Baltimore Tree Trust, Reservoir Hill Improvement Council, Forestry Division, and Parks Capital Improvements Division. In most cases, when the planting organizations were contacted for help in this study, they were able to provide additional planting records that had not been included in the original report to TreeBaltimore. The types of supporting documents they provided were updated planting lists, planting plans for sites, and aerial photos with outlines representing different phases of plantings. Other useful information was provided in personal interviews and site visits with organization staff.

The general outline for surveying a site involved the following steps:

1. Prepare data collection files in ArcGIS Online
2. For the specific site chosen for survey, gather all reported information from TreeBaltimore records
3. Contact planting organizations and acquire any additional documents or information about the site (examples of this in Appendix 2)
4. Travel to the site and use the Ipad 3 with 3G data connection and ESRI Collector application to measure the geographic location of each tree, and record the species and observed characteristics in the data collection files previously prepared in step 1
5. Produce a map of the site in the office using ArcGIS 10
6. Review map with planting organization to ensure trees had been assigned to the correct planting phase
7. Compare tree planting records with site survey results

Steps 4 and 5 in reality required multiple visits to produce accurate site maps. Details for the actual performance of this part of the survey process are summarized here:

1. <u>Preparation:</u> These tasks must be performed before going out into the field:
    a. acquire the species list and planting records for each site
    b. pack the iPads after checking the maps load correctly in Collector app
    c. plan the routes between the sites for that day
2. <u>Field Visit for Mapping and Data Collection:</u> At the survey site, iPads were used with the Collector app to collect the GPS locations and enter characteristics for every young tree present at the site. The difficulty of this process was dependent on:
    a. the number of trees to be mapped
    b. the availability of an accurate species list
    c. the availability of a planting plan
    d. the size of the site
    e. the distribution of the trees
    f. the GPS signal quality of the iPad

An accurate species list and planting plan greatly reduce the time spent surveying a site. Having to identify an unexpected tree species on site using the tree field guides takes several minutes, and thus greatly slows down the mapping process. Unfortunately, accurate planting records were not usually available, greatly slowing down mapping of nearly all sites. A high resolution 2011 aerial orthophotograph was available as a basemap in the Collector app, allowing for more accurate GPS location measurements of trees close to points of reference in the aerial photo.

Figure 10 shows a view of the screen in the Collector app on the iPad3. The red dots indicate trees, the green boundary indicates a group of trees planted on the same day, and the red boundary indicates the extent of the planting site.

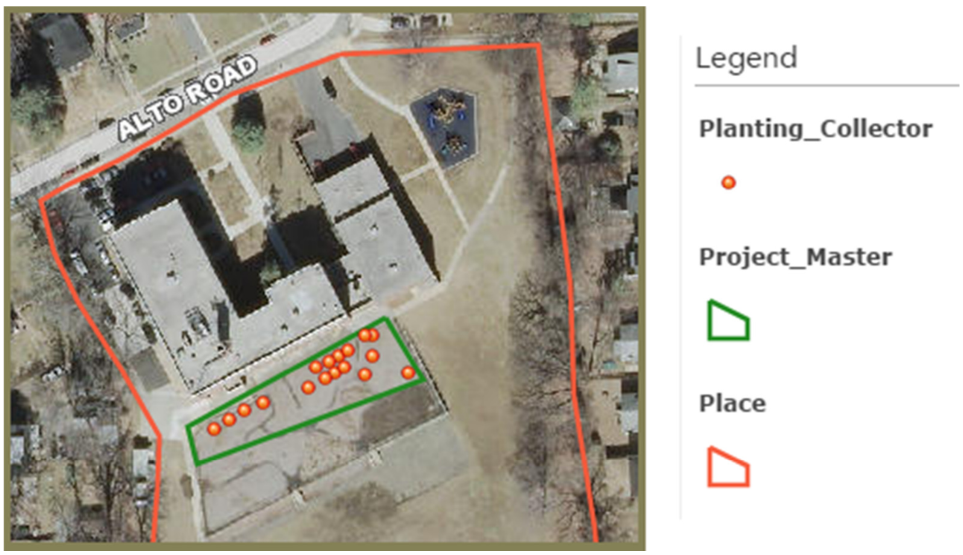

Figure 10: Collecting data using the ESRI Collector application

3. Production of 1st Draft Map: The 1st draft map of each site is a printed version of the geographic locations of all trees at a site overlaid on a high resolution aerial photograph, with trees and species labeled using codes. Producing these maps first required downloading the data from ArcGIS Online into ArcMap 10 and correcting typographic errors in the data entries collected in the database. Species were all assigned a unique code for each different combination of genus, species, and cultivar. A map document was prepared showing each section of the site at a legible scale, and then printed. High resolution aerial photos from December 2013 were available through the municipality's subscription to Pictometry, allowing for visual confirmation of the surveyed tree locations at some of the sites.
4. Field Correction: During the field correction process, the printed 1st draft maps were taken back to the site and used to compare with the actual arrangement of trees at

the site. Positional corrections of the locations of each tree were marked on the map by hand. The amount of time this step took depended on the quality of the original data collection, and the distribution of the trees on each site. Sites with large quantities of trees arranged randomly in single groups were the most difficult and time consuming. Sites with trees dispersed around visual points of reference on the aerial photographs were the quickest.

5. GIS Correction: Back in the office, the positional corrections marked on the maps during the second field visit were corrected in ArcMap 10. Additional notations and corrections were made to the data entries for each tree, as marked during the field correction.
6. Final Map: The final map was prepared in ArcMap 10 and sent to the planting organizations for their review. If necessary, steps 5 and 6 were repeated. An example of what appears in a final map is shown in Figure 11.

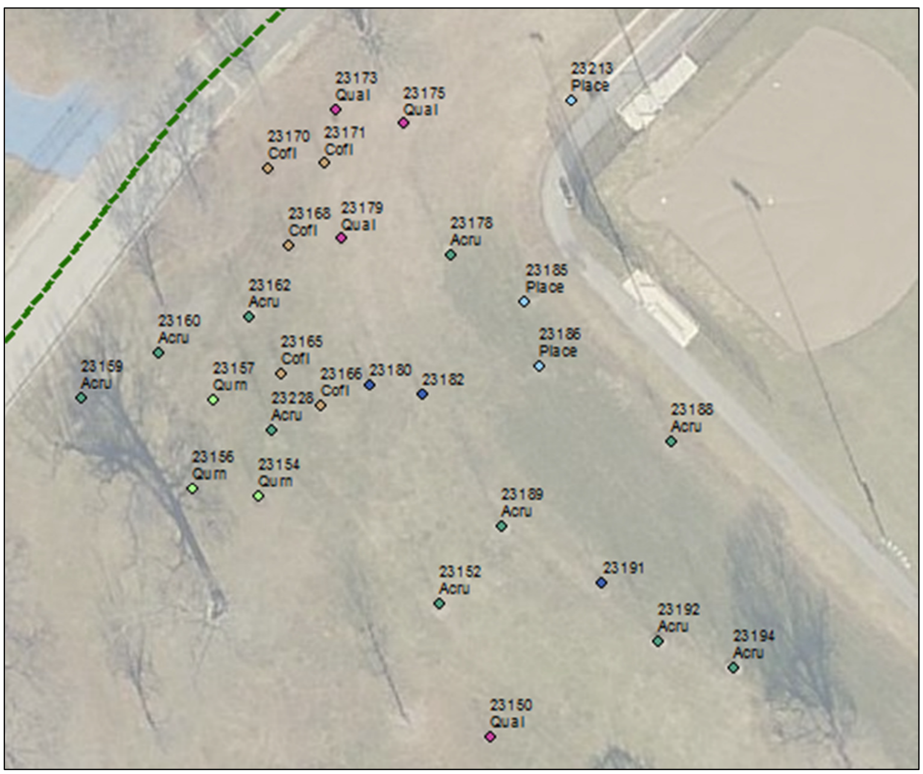

Figure 11: Example of Final Map, with trees labeled using ID numbers and species codes.

Data Collection and Database Schema

During the survey of each site, data was collected about each tree surveyed. As seen above in Figure 11, the tree points contain information such as an id number and species code. The full list of data collected about each tree was the following: (a) Species name, (b) Health status, (c) Size, (d) Notes, (e) Assessment date, (f) Assessor name, and (g) Tree id number. The 'species name' field was used to populate the full set of fields: (a1) Species code, (a2) Genus, (a3) Species, and (a4) Cultivar. The 'health status' field was used to indicate whether the tree was alive or dead, and whether any major conditions were affecting the live trees. The 'size' field was used to indicate the relative size of the tree in order to be able to match it to planting records. The 'notes' field was used to capture additional comments about the tree, and served as the source of proposed changes to the tree assessment collection form. The 'assessment date' and 'assessor name' fields were used for tracking purposes. The 'Tree id number' field was used to establish a unique ID for each of the individual points, which is necessary for connecting initial records to follow-up assessments of the same tree.

<u>Determining mortality</u>

To calculate mortality for a site, a total count of live trees was generated for each group of trees and then compared to the original records of trees planted at the site. The time since planting was measured in years, generalized to the year that the tree planting was performed (since exact planting dates were not available for most trees). The percent mortality was calculated by dividing the number of dead trees by the original number of trees planted. The average annual mortality rate was calculated by dividing the percent mortality by the time since planting. An example of a live tree and dead tree are shown in Figure 12.

Figure 12: Example of a dead tree at left, and a live tree at right.

Results

The mortality results for all sample sites are presented in Table 6. At each of the selected sites there were often multiple individual plantings, so the results are summarized by the duration in years since the planting. The mortality of first year plantings begins at a strong 18%, close to the 2nd and 3rd year plantings. Beyond the 3rd year the mortality gradually increases. The average annual rate is seen to decrease because the total mortality is spread among a greater number of years. The first year plantings represent a much larger sample than the previous years because the records were of better quality and could be successfully matched to the plantings.

All Site Types

Years Since Planting	Planted	Alive	Mortality	Annual Rate
1	2859	2344	18.0%	18.0%
2	700	584	16.6%	8.3%
3	415	329	20.7%	6.9%
4	538	403	25.1%	6.3%
5	176	106	39.8%	8.0%
6	261	184	29.5%	4.9%
9	150	72	52.0%	5.8%

Table 6: Mortality of all trees in sample, separated by years since planting.

The site types are a potential factor that may influence mortality rates, as identified in other studies. Table 7 presents the mortality results separated by the two main site types, compared side by side. The mortality of the park/school sites is much higher than the mortality of the street sites. The parks and schools are grouped together because the site conditions are very similar, whereas street sites are very different. The total number of street trees surveyed is much lower because they are composed of the street trees in the Reservoir Hill neighborhood as well as two medians that were selected in the random site selection.

Separated by Site Type

Years Since	Park/School Sites				Street Sites			
Planting	Planted	Alive	Mortality	Annual Rate	Planted	Alive	Mortality	Annual Rate
1	2754	2248	18.4%	18.4%	105	96	8.6%	8.6%
2	555	455	18.0%	9.0%	145	129	11.0%	5.5%
3	351	274	21.9%	7.3%	64	55	14.1%	4.7%
4	410	293	28.5%	7.1%	128	110	14.1%	3.5%
5	137	76	44.5%	8.9%	39	30	23.1%	4.6%
6	152	95	37.5%	6.3%	109	89	18.3%	3.1%
9	150	72	52.0%	5.8%				

Table 7: Mortality of trees in sample, separated by site type and years since planting.

Since the planting organizations are also a potential factor influencing mortality rates, it is worth dissecting the site types further. Table 8 isolates only the street trees, and presents results separated by planting organization type. At this level there is more variability between the planting years and between the organization types, possibly because the original quantity of trees planted in some of the categories is small.

Site Type: Street Trees

Years Since	NGO				Govt Agency			
Planting	Planted	Alive	Mortality	Annual Rate	Planted	Alive	Mortality	Annual Rate
1	30	27	10.0%	10.0%	75	69	8.0%	8.0%
2	48	34	29.2%	14.6%	97	95	2.1%	1.0%
3	55	47	14.5%	4.8%	9	8	11.1%	3.7%
4	105	89	15.2%	3.8%	23	21	8.7%	2.2%
5	15	12	20.0%	4.0%	24	18	25.0%	5.0%
6	52	47	9.6%	1.6%	57	42	26.3%	4.4%

Table 8: Mortality of street trees in sample, separated by organization type and by years since planting

Similarly, Table 9 isolates only the park/school trees, and presents results separated by planting organization type. As was noted in the materials and methods section, the government agencies reported very few plantings in the parks and schools. The mortality of the NGO plantings is similar for the first 3 years, despite there being a large number of trees surveyed. This may indicate the influence of other factors that influence year to year changes in performance.

Site Type: Park/School

Years Since	NGO				Govt Agency			
Planting	Planted	Alive	Mortality	Annual Rate	Planted	Alive	Mortality	Annual Rate
1	2408	1951	19.0%	19.0%	346	297	14.2%	14.2%
2	555	455	18.0%	9.0%				
3	351	274	21.9%	7.3%				
4	410	293	28.5%	7.1%				
5	137	76	44.5%	8.9%				
6	152	95	37.5%	6.3%				
9	150	72	52.0%	5.8%				

Table 9: Park and school trees surveyed in sample, separated by organization type and by years since planting

Since the first year sample of park/school sites is fairly large on its own, the NGO category is broken down into the major organizations only for the first year. Table 12 presents the first year mortality results broken down by major planting organization. Blue Water Baltimore is abbreviated BWB, Parks and People Foundation is PPF, and Parks Capital Improvements Division is BCRP Capital.

Site Type: Park/School				
First Year Mortality Rates of Major Organizations				
Org Type	Org Name	Planted	Alive	Mortality
Govt Agency	BCRP Capital	336	287	14.6%
NGO	BWB	905	730	19.3%
NGO	BWB/PPF	556	472	15.1%
NGO	PPF	823	638	22.5%
NGO	NGO Other	124	111	10.5%

Table 10: First year tree mortality rates in Park and School site types, separated by major planting organizations

Table 11 summarizes the survey results for each of the 47 selected sites, and Table 12 presents the full table of results separated by site, year, and planting organization (full tables are on next pages). The number of remaining live trees at the time of assessment was compared with the original quantity of trees planted in order to determine mortality. Six of the sites were inconclusive because the surveyed trees at those sites could not be matched to the records submitted by the planting organization, so they are omitted from the results. At many of the sites, the surveys revealed a series of successive planting years at the same site.

Site ID	Row Labels	Years Planted	Trees Planted	Alive	Mortality	Year Assessed
1	ACCE HS	2012-2013	43	31	27.9%	2014
2	Alexander Odum Park		Inconclusive			
3	Armistead Garden EMS	2008-2013	140	87	37.9%	2014
4	Baltimore IT Academy	2013	73	55	24.7%	2014
5	Belmont ES	2013	56	40	28.6%	2014
6	Booker Washington MS	2013	7	7	0.0%	2014
7	Cherry Hill Park	2013	514	437	15.0%	2014
8	Chinquapin Run Park - Midsection	2013	180	162	10.0%	2014
9	City College HS		Inconclusive			
10	Claremont HS	2012-2013	60	50	16.7%	2014
11	Clifton Park - Erdman	2008	50	41	18.0%	2014
12	Desoto Park	2013	71	59	16.9%	2014
13	Dr. Martin Luther King EMS	2013	62	56	9.7%	2014
14	Druid Hill Park	2014	169	137	18.9%	2015
15	Frederick Douglass HS	2010-2013	349	300	14.0%	2014
16	Green Street Academy	2013	28	27	3.6%	2014
17	Guilford EMS	2013	12	11	8.3%	2014
18	Gwynns Falls ES	2010	380	269	29.2%	2014
19	Gwynns Falls Leakin Park - Winan's	2013	23	20	13.0%	2014
20	Gwynns Falls Trail - Carroll Area	2013	110	67	39.1%	2014
21	Hampden ES	2013	14	13	7.1%	2014
22	Harford Heights EMS	2013	48	24	50.0%	2014
23	Harlem Park ES	2012	39	22	43.6%	2014
24	Herring Run Park - Armistead Gardens	2011	40	14	65.0%	2014
25	Herring Run Park - Brehms to Sinclair	2012-2013	211	144	31.8%	2014
26	Hillen Rd Median	2012	88	87	1.1%	2014
27	Hillen Triangle	2009	15	10	33.3%	2014
28	Jones Falls Trail	2013	140	123	12.1%	2014
29	Lake Montebello	2009	46	26	43.5%	2014
30	Maritime Industries HS	2011-2013	245	149	39.2%	2014
31	Mary Ann Winterling ES	2013	61	40	34.4%	2014
32	Matthew A Henson ES	2013	36	33	8.3%	2014
33	MERVO		Inconclusive			
34	Moravia Park EMS	2013	294	273	7.1%	2014
35	Morrell Park	2013	27	27	0.0%	2014
36	NACA Academy / North Harford Park	2013	90	76	15.6%	2014
37	New Era Academy	2011	234	212	9.4%	2014
38	Northeast MS	2008-2012	76	38	50.0%	2014
39	Paca and Atlantic Park		Inconclusive			
40	REACH HS	2005-2013	331	240	27.5%	2014
41	Reginald F Lewis HS	2013	123	104	15.4%	2014
42	Roosevelt Park	2014	24	20	16.7%	2015
43	Solo Gibbs Park	2013	12	11	8.3%	2014
44	Walter P. Carter EMS		Inconclusive			
45	Walther Ave Median	2013	11	11	0.0%	2014
46	Western HS		Inconclusive			
47	Reservoir Hill Neighborhood	2009-2014	572	470	17.8%	2015
	Grand Total		5104	4023	21.2%	

Table 11: Summary of survey results, separated by planting site.

Site ID	Site Name	Site Cat	Org Type	Main Org	Trees Planted	Alive	Mortality	Year Plant	Year Assess	Duration	Gen Mort Rate
Trees planted 1 year prior - each row represents a separate planting at a site											
1	ACCE HS	School	Gov Agency	BCRP Forestry	3	3	0.0%	2013	2014	1	0.0%
3	Armistead Garden EMS	School	NGO	BWB/PPF	42	35	16.7%	2013	2014	1	16.7%
4	Baltimore IT Academy	School	NGO	PPF	73	55	24.7%	2013	2014	1	24.7%
5	Belmont ES	School	NGO	PPF	56	40	28.6%	2013	2014	1	28.6%
6	Booker Washington MS	School	NGO	BWB	7	7	0.0%	2013	2014	1	0.0%
7	Cherry Hill Park	Park	NGO	BWB/PPF	514	437	15.0%	2013	2014	1	15.0%
8	Chinquapin Run Park - Midsection	Park	NGO	BWB	60	55	8.3%	2013	2014	1	8.3%
8	Chinquapin Run Park - Midsection	Park	NGO	NGO Other	120	107	10.8%	2013	2014	1	10.8%
10	Claremont HS	School	NGO	BWB	26	19	26.9%	2013	2014	1	26.9%
12	Desoto Park	Park	NGO	PPF	71	59	16.9%	2013	2014	1	16.9%
13	Dr. Martin Luther King EMS	School	NGO	PPF	62	56	9.7%	2013	2014	1	9.7%
14	Druid Hill Park	Park	Gov Agency	BCRP Capital	169	137	18.9%	2014	2015	1	18.9%
15	Frederick Douglass HS	School	Gov Agency	BCRP Forestry	7	7	0.0%	2013	2014	1	0.0%
15	Frederick Douglass HS	School	NGO	BWB	90	61	32.2%	2013	2014	1	32.2%
16	Green Street Academy	School	NGO	PPF	28	27	3.6%	2013	2014	1	3.6%
17	Guilford EMS	School	NGO	BWB	12	11	8.3%	2013	2014	1	8.3%
19	Gwynns Falls Leakin Park - Winan's Meadow	Park	NGO	PPF	23	20	13.0%	2013	2014	1	13.0%
20	Gwynns Falls Trail - Carroll Area	Park	NGO	BWB	110	67	39.1%	2013	2014	1	39.1%
21	Hampden ES	School	NGO	NGO Other	4	4	0.0%	2013	2014	1	0.0%
21	Hampden ES	School	NGO	BWB	10	9	10.0%	2013	2014	1	10.0%
22	Harford Heights EMS	School	NGO	PPF	48	24	50.0%	2013	2014	1	50.0%
25	Herring Run Park - Brehms to Sinclair	Park	NGO	BWB	101	61	39.6%	2013	2014	1	39.6%
28	Jones Falls Trail	Park	Gov Agency	BCRP Capital	140	123	12.1%	2013	2014	1	12.1%
30	Maritime Industries HS	School	NGO	BWB	56	52	7.1%	2013	2014	1	7.1%
30	Maritime Industries HS	School	NGO	PPF	69	19	72.5%	2013	2014	1	72.5%
31	Mary Ann Winterling ES	School	NGO	PPF	61	40	34.4%	2013	2014	1	34.4%
32	Matthew A Henson ES	School	NGO	PPF	36	33	8.3%	2013	2014	1	8.3%
34	Moravia Park EMS	School	NGO	BWB	150	133	11.3%	2013	2014	1	11.3%
34	Moravia Park EMS	School	NGO	PPF	144	140	2.8%	2013	2014	1	2.8%
35	Morrell Park	Park	Gov Agency	BCRP Capital	27	27	0.0%	2013	2014	1	0.0%
36	NACA Academy / North Harford Park	School	NGO	BWB	90	76	15.6%	2013	2014	1	15.6%
40	REACH HS	School	NGO	BWB	181	168	7.2%	2013	2014	1	7.2%
41	Reginald F Lewis HS	School	NGO	PPF	123	104	15.4%	2013	2014	1	15.4%
42	Roosevelt Park	Park	NGO	PPF	24	20	16.7%	2014	2015	1	16.7%
43	Solo Gibbs Park	Park	NGO	BWB	12	11	8.3%	2013	2014	1	8.3%
45	Walther Ave Median	Street	NGO	BWB	11	11	0.0%	2013	2014	1	0.0%

Table 12: Full site results aggregated by year, planting organization, and site type

Site ID	Site Name	Site Cat	Org Type	Main Org	Trees Planted	Alive	Mortality	Year Plant	Year Assess	Duration	Gen Mort Rate
47	Reservoir Hill Neighborhood	Park	NGO	PPF	5	1	80.0%	2014	2015	1	80.0%
47	Reservoir Hill Neighborhood	Street	Gov Agency	BCRP Forestry	75	69	8.0%	2014	2015	1	8.0%
47	Reservoir Hill Neighborhood	Street	NGO	NGO Other	17	15	11.8%	2014	2015	1	11.8%
47	Reservoir Hill Neighborhood	Street	NGO	PPF	2	1	50.0%	2014	2015	1	50.0%

Trees planted 2 years prior - each row represents a separate planting at a site

Site ID	Site Name	Site Cat	Org Type	Main Org	Trees Planted	Alive	Mortality	Year Plant	Year Assess	Duration	Gen Mort Rate
1	ACCE HS	School	NGO	NGO Other	40	28	30.0%	2012	2014	2	15.0%
10	Claremont HS	School	NGO	BWB	34	31	8.8%	2012	2014	2	4.4%
15	Frederick Douglass HS	School	NGO	BWB	250	231	7.6%	2012	2014	2	3.8%
23	Harlem Park ES	School	NGO	BWB	39	22	43.6%	2012	2014	2	21.8%
25	Herring Run Park - Brehms to Sinclair	Park	NGO	BWB	110	83	24.5%	2012	2014	2	12.3%
26	Hillen Rd Median	Street	Gov Agency	BCRP Forestry	88	87	1.1%	2012	2014	2	0.6%
30	Maritime Industries HS	School	NGO	BWB	45	31	31.1%	2012	2014	2	15.6%
38	Northeast MS	School	NGO	BWB	20	17	15.0%	2012	2014	2	7.5%
47	Reservoir Hill Neighborhood	Park	NGO	BWB	13	11	15.4%	2013	2015	2	7.7%
47	Reservoir Hill Neighborhood	Park	NGO	NGO Other	1	1	0.0%	2013	2015	2	0.0%
47	Reservoir Hill Neighborhood	Park	NGO	PPF	3	0	100.0%	2013	2015	2	50.0%
47	Reservoir Hill Neighborhood	Street	Gov Agency	BCRP Forestry	9	8	11.1%	2013	2015	2	5.6%
47	Reservoir Hill Neighborhood	Street	NGO	BWB	44	32	27.3%	2013	2015	2	13.6%
47	Reservoir Hill Neighborhood	Street	NGO	NGO Other	4	2	50.0%	2013	2015	2	25.0%

Trees planted 3 years prior - each row represents a separate planting at a site

Site ID	Site Name	Site Cat	Org Type	Main Org	Trees Planted	Alive	Mortality	Year Plant	Year Assess	Duration	Gen Mort Rate
24	Herring Run Park - Armistead Gardens	Park	NGO	BWB	40	14	65.0%	2011	2014	3	21.7%
30	Maritime Industries HS	School	NGO	BWB	75	47	37.3%	2011	2014	3	12.4%
37	New Era Academy	School	NGO	BWB	234	212	9.4%	2011	2014	3	3.1%
47	Reservoir Hill Neighborhood	Park	NGO	NGO Other	2	1	50.0%	2012	2015	3	16.7%
47	Reservoir Hill Neighborhood	Street	Gov Agency	BCRP Forestry	9	8	11.1%	2012	2015	3	3.7%
47	Reservoir Hill Neighborhood	Street	NGO	NGO Other	55	47	14.5%	2012	2015	3	4.8%

Trees planted 4 years prior - each row represents a separate planting at a site

Site ID	Site Name	Site Cat	Org Type	Main Org	Trees Planted	Alive	Mortality	Year Plant	Year Assess	Duration	Gen Mort Rate
15	Frederick Douglass HS	School	Gov Agency	BCRP Forestry	2	1	50.0%	2010	2014	4	12.5%
18	Gwynns Falls ES	School	NGO	BWB	380	269	29.2%	2010	2014	4	7.3%

Table 12 (cont.): Full site results aggregated by year, planting organization, and site type

47	Reservoir Hill Neighborhood	Park	NGO	NGO Other	15	12	20.0%	2011	2015	4	5.0%
47	Reservoir Hill Neighborhood	School	NGO	NGO Other	15	12	20.0%	2011	2015	4	5.0%
47	Reservoir Hill Neighborhood	Street	Gov Agency	BCRP Forestry	23	21	8.7%	2011	2015	4	2.2%
47	Reservoir Hill Neighborhood	Street	NGO	NGO Other	105	89	15.2%	2011	2015	4	3.8%

Trees planted 5 years prior - each row represents a separate planting at a site

Site ID	Site Name	Site Cat	Org Type	Main Org	Trees Planted	Alive	Mortality	Year Plant	Year Assess	Duration	Gen Mort Rate
3	Armistead Garden EMS	School	NGO	BWB	56	23	58.9%	2009	2014	5	11.8%
27	Hillen Triangle	Park	NGO	BWB	15	10	33.3%	2009	2014	5	6.7%
29	Lake Montebello	Park	NGO	BWB	46	26	43.5%	2009	2014	5	8.7%
47	Reservoir Hill Neighborhood	Park	NGO	NGO Other	20	17	15.0%	2010	2015	5	3.0%
47	Reservoir Hill Neighborhood	Street	Gov Agency	BCRP Forestry	24	18	25.0%	2010	2015	5	5.0%
47	Reservoir Hill Neighborhood	Street	NGO	NGO Other	15	12	20.0%	2010	2015	5	4.0%

Trees planted 6 years prior - each row represents a separate planting at a site

Site ID	Site Name	Site Cat	Org Type	Main Org	Trees Planted	Alive	Mortality	Year Plant	Year Assess	Duration	Gen Mort Rate
3	Armistead Garden EMS	School	NGO	BWB	42	29	31.0%	2008	2014	6	5.2%
11	Clifton Park - Erdman	Park	NGO	BWB	50	41	18.0%	2008	2014	6	3.0%
38	Northeast MS	School	NGO	BWB	56	21	62.5%	2008	2014	6	10.4%
47	Reservoir Hill Neighborhood	Park	Gov Agency	BCRP Forestry	3	0	100.0%	2009	2015	6	16.7%
47	Reservoir Hill Neighborhood	Park	NGO	NGO Other	1	1	0.0%	2009	2015	6	0.0%
47	Reservoir Hill Neighborhood	School	NGO	NGO Other	3	3	0.0%	2009	2015	6	0.0%
47	Reservoir Hill Neighborhood	Street	Gov Agency	BCRP Forestry	57	42	26.3%	2009	2015	6	4.4%
47	Reservoir Hill Neighborhood	Street	NGO	NGO Other	52	47	9.6%	2009	2015	6	1.6%

Trees planted 9 years prior - each row represents a separate planting at a site

Site ID	Site Name	Site Cat	Org Type	Main Org	Trees Planted	Alive	Mortality	Year Plant	Year Assess	Duration	Gen Mort Rate
40	REACH HS	School	NGO	BWB	150	72	52.0%	2005	2014	9	5.8%

Table 12 (cont.): Full site results aggregated by year, planting organization, and site type

Discussion

Comparing Mortality to Preceding Studies

The US EPA study published in 2004 proposed categories for what could be considered high, average, and low mortality rate scenarios for planted urban trees during their establishment phase. The high mortality scenario was assigned an annual mortality rate of 7-9%, the average mortality scenario is 5-7%, and the low mortality scenario is 3-5% (US EPA 2004). This present study has revealed average first year mortality rates well beyond the upper range of the US EPA high mortality scenario. However, the average annual mortality rates for year two and beyond are between 4.9-8.3%, all of which fall within the US EPA classification. This seems to imply that the mortality during the first year after planting is much higher than in subsequent years, resulting in a lower average annual mortality rate over time.

Annual or semi-annual intervals would permit a better understanding of the first and second year high mortality rates. The average annual mortality rate presented in studies is highly dependent on how many years the study contains (Roman & Scatena, 2011). As was revealed in compilations of mortality studies, the length and interval of previous mortality studies vary widely (US EPA, 2004). Nevertheless, the average annual mortality rate is a common figure that can be compared between studies.

For park/school trees the average annual mortality rate was 18.4% after one year, and 9.0% for trees after the second year. Roman and Scatena (2011) compiled a number of studies reporting annual mortality rates between 80.3-99.7%. For street trees the average annual mortality rate was 8.6% after one year, and 5.5% after two years. In New York City, Lu et al. (2010) found a street tree mortality of 8.7% after two years, indicating an annual average mortality rate of 4.4%. In Oakland, California Nowak et al. 1990 found a street tree mortality of 34%, with an annual rate of 19%. This places Baltimore's park/school tree plantings and street tree plantings within the range of mortality rates reported by other studies.

Effect of Cluster Sampling and Difficulties at the Selected Sites

The first year mortality results were much more heavily represented in the sample because many of the older individual plantings at the sites were inconclusive. When the surveys were performed, the older individual plantings were much harder to match to the TreeBaltimore records or the supplemental documents provided by the organizations. All plantings that could not be matched were eliminated from the results. The discussion below explores the implications of the sampling method used, and explores the meaning of individual site results.

The preliminary results presented in Table 11 reveal potential problems in using the sample to draw conclusions about the whole population. Cluster sampling was used to randomly select sites, and then perform a full inventory at each of the selected sites. While cluster sampling has the benefit of being a cost effective probability sampling technique, it is only effective if clusters are representative of the population, exhibiting more within-cluster variability than between-cluster variability (Daniel, 2011). Table 11 immediately reveals clusters of widely different sizes, ranging from the smallest cluster with a population of 7, to the largest cluster with a population of 514 (excluding the Reservoir Hill neighborhood). The average cluster size is 113, and the median is 62, further indicating that the cluster populations are not normally distributed and are positively skewed.

The random sample of 46 clusters was taken from plantings reported in 2013 and 2012, and the site surveys were performed in 2014. This was done to be able to compare mortality rates of sites at year 1 and sites at year 2. However, Table 11 indicates that some of the clusters have plantings spanning several years, and other clusters were planted well before 2012. This happened due to a combination of poor planting records and the sampling design decision to inventory all individuals at selected sites. Once the sites had been randomly selected, all planting records for those sites were extracted from the TreeBaltimore planting records. The planting organizations indicated for each site in the TreeBaltimore records were contacted and additional information was requested, such as final planting lists for the site, planting plans, and boundaries of planting phases. Sites were visited and all trees were inventoried, attempting to find and document all of the plantings indicated in the records.

<u>Every single one</u> of the 47 sites had problems with matching the surveys to the records for those sites, leading to the decision to present the results as total counts only, and not broken down by species. Presented here are a selection of the problems encountered at the sites: (a) there were more trees at the site than there were in the records, indicating missing records; (b) the types and counts of species present at the site do not match the species in the records, indicating incorrect planting lists reported for the site; (c) different phases of plantings overlapped and could not be distinguished from each other with the available records, preventing a planting year from being assigned to the tree; (d) trees that previously died had been subsequently replaced but not reported, introducing errors into mortality calculations; (e) planting lists and plans reflected only the planned planting, and were never corrected to show what was actually planted; (f) reported plantings could not be found at the site, indicating total mortality, reporting error, or surveyor error.

The combination of these problems greatly slowed this study and required repeated consultation with the planting organizations to attempt to sort out the records for each site. Because of the near-universal mismatch of species between records and sites, the species information was omitted from the results. Each of the planting organizations confirmed that species substitutions commonly occurred at the time of planting, but were not recorded, however the total count of trees stayed the same. All trees that were not able to be matched to a specific planting record indicating the year of the planting were eliminated from the final results. This is why there are sites that do not include the planting years of 2012 or 2013, because they could not be matched. The results depict all trees that could be successfully matched to specific records, disregarding species data.

Separation of the results by site and year

Table 12 breaks down the planting sites by length of time in the ground, as well as by their planting organization. These represent the individual planting projects undertaken by specific planting organizations at each site. The quantity of trees planted is very low in some cases, usually because it reflects only a small portion of a larger project. For example, at Site 15 the Forestry Division planted 7 trees in 2013, because it was part of a larger citywide planting project that had 7 trees allocated to that specific site. Comparing the individual groups of plantings at each site reveals some interesting insights.

Figure 13 is a plot chart showing the percent mortality of each planting at age 1, produced from the data in Table 12. Each dot represents a group of trees planted at one site by one planting organization during the same year, and the dots are symbolized by organization type. As expected, plantings with small initial population display wider variability, however there is evidence of high mortality in some cases. Three individual plantings of initial population close to 100 that display a mortality of 30-40% at Age 1. There is also one planting of 69 trees that experienced 72.5% mortality in the first year, and another planting of 48 trees that experienced 50% mortality. For the small sample of government agency groups, there were none that surpassed a mortality of 20%, however only 3 plantings of over 40 trees were analyzed.

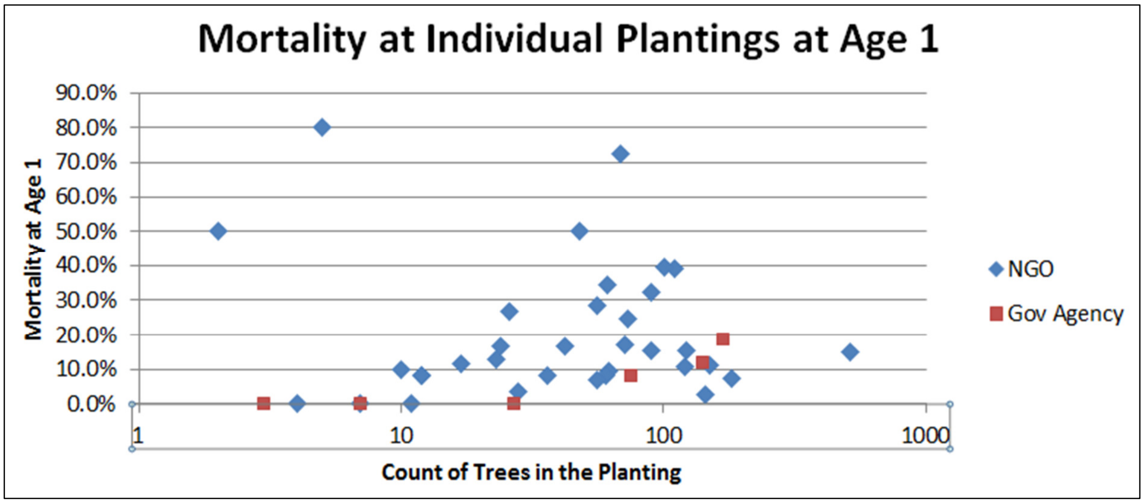

Figure 13: Scatter plot of mortality at individual plantings at age 1, produced from the data in Table 12

While individual plantings are not representative of the whole population this still indicates that it is possible for plantings containing over 40 trees to experience 1st year mortality of over 30%. Figure 14 is a plot chart of mortality for all plantings over 40 trees, plotted by years since planting. This chart allows us to look at plantings beyond year one, and reveals a wide variability in mortality rates between sites. By year 3, the minimum mortality of any site is 9%, and there is an instance at year 6 of 10% mortality. Beyond year 4, there are instances of mortality between 40-70%, however there are also examples of plantings in year 6 with mortality between 10-31%.

Admittedly there are few plantings in the sample for the later years, but a chart like Figure 14 allows forest managers to see possible outcomes of planting sites over time. As additional sites are surveyed and data is added to the chart, it will be possible to determine the expected ranges of mortality rates. In this present case there is evidence of a wide variety of mortality in sites extending through the establishment phase of the trees. In this case it will help the forest managers establish what is considered high mortality versus low mortality for the individual plantings.

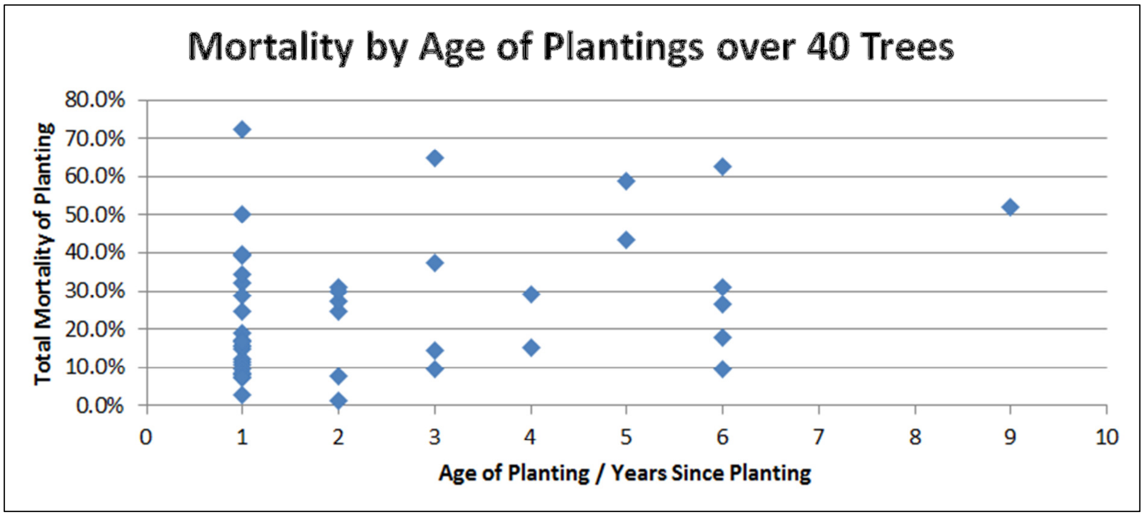

Figure 14: Scatter plot of mortality at individual plantings by the age of the planting, produced from the data in Table 12.

Limitations and Recommendations

The study encountered several limitations that serve as inspiration for further work. A major limitation was that sites reported only the total counts of trees without any other characteristics. To allow for proper comparison among sites, reports should also include details such as species, size, tree protective devices, and methods used by the planting organization. The original species and size information recorded for the tree plantings was not reliable, so could not be compared to the surveyed species. A major limitation was not being able to perform a stratified sample, especially since the clusters did not appear to be representative samples. The tree planting recording methods need to be improved so that individual trees can be randomly sampled at group plantings. The date of planting and date of assessment should be more precisely measured to be able to more accurately determine the duration between planting and assessment.

The date of planting and date of assessment should be more precisely measured to be able to more accurately determine the duration between planting and assessment. The brief duration of this study also did not allow for more than one mortality assessment per planting, thus the mortality rates calculated for different age plantings did not reflect the same climatic conditions. An extension of this study following specific cohorts of trees over several intervals of assessments would allow the changing mortality rates to be better described.

The classification of the site types, although useful, depended more on the surroundings than the immediate location of the tree. For example, if a tree was in a park, but in a sidewalk planting space, it was still designated as park. The site type classification would be more reflective of the conditions for the tree if it was categorized by immediate ground and planting location qualities. Additional site details like the types of tree protective devices, ground covering, and soil conditions would allow for further investigation.

Conclusions

This study revealed the mortality rates of trees planted in park, school, and street sites over the last several years in Baltimore, Maryland, USA. During the establishment phase, the average annual mortality rates of trees planted at street sites were found to be lower than for park/school sites. When compared to previous studies the average annual mortality rates for both site types were found to be within the range of those published by previous studies. Mortality rates at individual plantings and sites were shown to widely vary, indicating that cluster sampling may not produce a representative sample of the population. The NGO planting organizations produced higher initial mortality rates than the government agencies, but over longer time periods had similar average annual mortality rates. The differences in performance could be due to numerous factors, such as specific origin of the sampled trees, planting methods, soil type and conditioning, cultivation methods, environmental exposure, etc. A complete set of data including those variables was not available for this study. Future research could be designed to investigate those factors in detail.

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Appendix 1: City Tree Planting Program Websites [All accessed in June 2015]

North America:

- Los Angeles (LA), California
  - Million Trees LA: http://www.milliontreesla.org/mtabout1.htm
  - City Plants: http://www.cityplants.org/
- New York City (NYC), New York
  - Million Trees NYC: http://www.milliontreesnyc.org/html/home/home.shtml
  - 800,000th tree planted by mayor: http://www1.nyc.gov/office-of-the-mayor/news/365-13/mayor-bloomberg-plants-800-000th-tree-million-trees-nyc-initiative-announces-completion-of/#/0
- Chicago, Illinois
  - Street tree planting program: http://naturalsystems.uchicago.edu/urbanecosystems/calumet/cdrom/plans/CoCUrbanTreePlantList.pdf
  - Chicago urban forestry agency: http://www.cityofchicago.org/city/en/depts/streets/provdrs/forestry.html/
- Houston, Texas
  - Trees for Houston: http://www.treesforhouston.org/
- Philadelphia, Pennsylvania
  - TreePhilly: http://treephilly.org/
- Phoenix, Arizona
  - Tree & Shade Master Plan: https://www.phoenix.gov/parkssite/Documents/T%20and%20A%202010.pdf
- Baltimore, Maryland
  - TreeBaltimore: http://treebaltimore.org/
  - Baltimore Forestry Division: http://bcrp.baltimorecity.gov/ForestryTreeServices.aspx
- Washington, DC
  - Casey Trees: http://caseytrees.org/
  - DC Department of Transportation Urban Forestry: http://ddot.dc.gov/page/ddot-urban-forestry
- Miami, Florida
  - Million Trees Miami: http://milliontrees.miamidade.gov/
- Pittsburgh, Pennsylvania
  - Tree Pittsburgh: http://treepittsburgh.org/
- Nationwide

- Nature Conservancy Billion Trees: http://www.plantabillion.org/urban-trees/
- Arbor Day Foundation: https://www.arborday.org/
- American Forests: https://www.americanforests.org/
- Alliance for Community Trees: http://actrees.org/

Mediterranean:

It was difficult to find websites for citywide tree planting campaigns or programs in Mediterranean countries, suspectedly due to language barrier. The results below reflect only Spanish sources due to the author's basic knowledge of that languages. There is ample evidence of many separate planting efforts and volunteer planting projects in news media, pointing to existence of such programs. The parks/gardens departments, and street departments also refer to tree management activities on their websites. However, it was difficult to find a website for a central organization linking all or most of the tree planting initiatives taking place across a city. Performing internet searches using English terms literally translated into Spanish often did not work, as different local terms and phrases are being used to refer to urban forestry activities. It is also likely that internet websites are not used to display and distribute such information in the same way as in North America.

- Nationwide Spain:
  - Listing of NGO and volunteer organizations for tree planting throughout Spain: http://plantararboles.blogspot.com/2011/06/una-idea.html
  - 9 tree planting initiatives throughout Spain: http://www.consumer.es/web/es/medio_ambiente/naturaleza/2014/02/03/219236.php
- Seville, Spain:
  - Parks and gardens plans to plant 8,000 trees: http://www.diariodesevilla.es/article/sevilla/2019555/zoido/promete/plantar/arboles/su/segundo/mandato.html
  - Friends of parks community group with tree stewardship activities: https://jardinesdelaoliva.wordpress.com/tag/arboles-de-sevilla/
- Murcia, Spain:
  - "Plantemos para Murcia 2010" planting campain of tens of thousands of trees: http://www.murcia.es/medio-ambiente/parquesyjardines/inicioplantemos.asp
  - Volunteer solicitation for planting 12,000 trees: http://noticias.lainformacion.com/espana/ayuntamiento-murcia-invita-a-

ciudadanos-a-plantar-mas-de-12-000-arboles-que-ayuden-a-limpiar-el-aire-de-contaminacion_R35YDC6Vcgm4lAnxAwZCM3/

- Palencia, Spain:
  - Organization for volunteers planting on public property: https://ecologistaspalencia.wordpress.com/2014/01/09/jornadas-de-trabajo-altruista-plantando-arboles-y-arbustos/
- Barcelona, Spain:
  - Street tree management and measurements: http://w110.bcn.cat/MediAmbient/Continguts/Vectors_Ambientals/Espais_Verds/D
- Madrid, Spain:
  - Volunteer tree planting project in large park: http://www.abc.es/madrid/20150111/abci-parque-felipe-201501102028.html

Appendix 2: Planting Reporting Methods

These are the standard tree reporting forms that have been used by the Baltimore City Forestry Division and the TreeBaltimore program. Also included are some examples of alternate reporting methods.

BCRP Forestry - Standard Form (2008 - Present)
Property Address
Zip Code
Quantity
Species
Other Info
Date Plant

Figure 1

Figure 1 shows the standard form that is used by the Forestry Division to report the plantings that are performed by its contractors. The great majority of the Forestry Division's plantings are performed along the streets. While many of the records have unique addresses for each tree, there are many instances where several trees share the same address. The 'Other Info' field is used to write notes about the location of the tree, however it is not always used. With the information captured in this form, it is difficult to uniquely identify a tree if there is more than one tree present at the specified address.

Standard Form for all trees (2012 - 2013)
Site Type
Property Address
Latitude
Longitude
Zip code
Common Name
Genus
Species
Quantity
Container Size
Caliper
New/Infill/replacement
Date Planted
Lead Agency
Planted By
Maintained by
Funding Source
Neighborhood
Notes

Figure 2

Figure 2 shows the standard form that was developed by Jen Kullgren, a past employee of the TreeBaltimore program. This form was developed and distributed to all planting organizations in order to collect planting records in a standard format. This greatly facilitated the compilation of data from the various reporting organizations, but certain problems with the form prompted its modification in 2014.

In this form, each tree was required to have its own record, even if it shared all of the characteristics with other trees planted at the same location. The reason for that was so each tree record could hold a unique latitude and longitude. For individual street trees this is not a problem since each has a different address so it makes sense to list them separately. For trees planted in groups, using the form increased the potential for errors, it was time consuming, and produced a table that was visually difficult to read.

Place_Name	Genus	Species	Quant	Date_Plant
Solo Gibbs	Ulmus	americana	1	2008-11-01
Solo Gibbs	Ulmus	americana	1	2008-11-01
Solo Gibbs	Ulmus	americana	1	2008-11-01
Solo Gibbs	Ulmus	americana	1	2008-11-01
Solo Gibbs	Ulmus	americana	1	2008-11-01
Solo Gibbs	Ulmus	americana	1	2008-11-01
Solo Gibbs	Ulmus	americana	1	2008-11-01
Solo Gibbs	Ulmus	americana	1	2008-11-01
Solo Gibbs	Ulmus	americana	1	2008-11-01
Solo Gibbs	Ulmus	americana	1	2008-11-01
Solo Gibbs	Ulmus	americana	1	2008-11-01
Solo Gibbs	Cercis	canadensis	1	2008-11-01
Solo Gibbs	Cercis	canadensis	1	2008-11-01
Solo Gibbs	Cercis	canadensis	1	2008-11-01
Solo Gibbs	Cercis	canadensis	1	2008-11-01
Solo Gibbs	Cercis	canadensis	1	2008-11-01
Solo Gibbs	Cercis	canadensis	1	2008-11-01
Solo Gibbs	Cercis	canadensis	1	2008-11-01
Solo Gibbs	Cercis	canadensis	1	2008-11-01
Solo Gibbs	Cercis	canadensis	1	2008-11-01

Figure 3

Figure 3 shows an abbreviated example of a table where individual trees with identical characteristics require separate form entries. Figure 3 represents a planting of 11 Ulmus Americana and 9 Cercis Canadensis at Solo Gibbs Park in 2008. It is difficult to prepare and to read. Since the individual locations of the trees are not known, the reported plantings could be presented in an aggregated format without affecting the quality of the data.

The shortcomings of the standard form inevitably lead to many of the planting organizations not following the standard reporting form for group plantings, and instead substituting their own recording method. The different techniques revealed inconsistencies in the data that was collected and transferred to TreeBaltimore.

Figure 4 shows an example of a table presented by Blue Water Baltimore, an NGO planting organization, used to report group plantings in a more efficient and legible format. Several planting organizations were actively using modified versions of this type of table. As a result, the TreeBaltimore standard reporting form was modified in 2014 to include a standard version of this table for reporting group plantings.

Common	Genus	Species	Cultivar	NOTES	Size	Caliper	Total	Solo Gibbs Park- COMPLETED	Mount Pleasant Golf Course- COMPLETED	Claremont HS- COMPLETED	Frederick Douglass HS--COMPLETED	Reach School- Civic Works--COMPLETED	Booker T. Washington MS--COMPLETED	Hampden EMS--COMPLETED
Red Maple	Acer	Rubrum			7 gal.	1"	40		4		15	6		2
Sugar Maple BB					BB		0							
Red Maple BB					BB		0							
Red Maple	Acer	Rubrum	October Glory		15 gal.	1.5"	0							
Red Maple	Acer	Rubrum			3 gal.	1/2"	15							
Serviceberry	Amelanchier	canadensis			3 gal	1/2"	16					6		
Shadblow Serviceberry	Amelanchier	canadensis	single-stem		7 gal.	1"	0							
Pawpaw	Asimina	triloba			7 gal.	1"	0							
Hornbeam	Carpinus	caroliniana			5 gal	1/2"	17							2
Hornbeam	Carpinus	caroliniana			3 gal	1/2"	20							
Mockernut Hickory	Carya	tomentosa			3 gal	1/2"	5							
Mockernut Hickory	Carya	tomentosa			7 gal.	1"	2	2						
Hackberry BB	Celtis	occidentalis			BB	1.5"	5							
Hackberry	Celtis	occidentalis			3 gal	1/2"	10							

Figure 4

Figure 5 and 6 show examples of simple lists submitted by NGO planting organizations despite there being a standard reporting form distributed by TreeBaltimore. All deviations from the standard form exhibited the commonality of being able to report multiple quantities of trees that otherwise shared identical characteristics and address.

All planting reports received in alternate formats were converted to the standard reporting form by TreeBaltimore staff. However, due to the lack of following a standard, many of the alternate forms were missing certain fields or characterizing qualities about the trees. The most common missing information were the container type, size at purchase, cultivar, and site type.

Mt. Vernon Trees Planted - Fall 2013

Address	#	Tree Type
801 N Charles	2	American Elm
819 N Charles	1	American Elm
802 N Charles	1	American Elm
930 N Charles	1	American Elm
929 N Charles	1	American Elm
1028 N Charles	1	Zelkova
1009 N Charles	1	Zelkova
1015 N Charles	1	Zelkova
1019 N Charles	1	Zelkova
1100 N Charles	1	Zelkova
1200 N Charles (entire even side)	10	Red Maple
1300 N Charles	1	Red Maple
1320 N Charles	1	Red Maple
1301 N Charles	1	Red Maple
1305 N Charles	1	Red Maple
1704 N Charles (Charles North)	1	Zelkova
1728 N Charles (Charles North)	2	Zelkova
1800 N Charles (Charles North)	1	Zelkova

Figure 5

While inconsistent, the alternate reporting methods from the NGOs presented good ideas that were eventually incorporated into the new TreeBaltimore tree planting reporting standard in 2014. Figure 7 displays a method of tracking group plantings that was being used by the NGO Blue Water Baltimore. Google Earth was used to draw boundaries for each group planting, and a planting list was generated for each site each year. This level of data greatly helped the process of surveying planting sites, and made it possible to distinguish between phases at sites that had been planted on consecutive years.

Tree Plantings by Roland Park Civic League, 2012 and 2013
Contractor: Parks and People Foundation
(all trees 2-2 ½" caliper planted in verge unless otherwise noted)

Spring 2012 (27 total)

203 Club Rd. Allee Elm (2)
208 Club Rd. Redmond Linden
215 Club Rd. Dogwood
7 Elmhurst Rd. Sweetgum
21 Elmwood Rd. Allee Elm (2)
1 Englewood Rd. Red Oak (died, replaced Fall, 2012)
5105 Falls Rd. Terrace Winter King Hawthorn planted in median
5307 Falls Rd. Terrace Allee Elm
106 Hawthorn Rd. Honey Locust
121 Hawthorn Rd. Honey Locust
301 Oakdale Rd. Red Oak (2)
211 Ridgewood Rd. Dogwood planted in yard.
4610 Roland Ave. Red Oak (died, replanted fall, 2012)
4715 Roland Ave. Allee Elm
104 St. John's Rd. Patriot Elm (died, replanted Fall 2012)
300 Somerset Rd. Red Oak (died, replanted fall 2012)
216 Woodlawn Rd. Allee Elm planted at 3-3 ½" caliper
218 Woodlawn Rd. Princeton Elm, Patriot Elm plus 2 October Glory Maples in yard
318 Woodlawn Rd. Honey Locust
415 Woodlawn Rd. Gingko (2)

Fall 2012 (17 total)

Figure 6

The styles of certain planting planning documents also proved useful. Figure 8 and 9 display planting plants prepared by planting coordinators, which the planting organizations use to guide their planting operations. Planting plans are like construction documents for tree planting organizations. As is the case with many plans and construction documents, when the plantings are performed there are modifications made to accommodate for unforeseen circumstances and other changes made at the planting site by the planting coordinator. While these planting plans don't show the last minute changes made at the planting site, they demonstrate an effective method of individually identifying tree locations at group planting sites that share the same address.

Figure 8 is a planting plan produced by a planting coordinator at the NGO Parks & People Foundation. Figure 9 is a planting plan produced by a landscape architect contractor hired by the Baltimore City Department of Recreation and Parks.

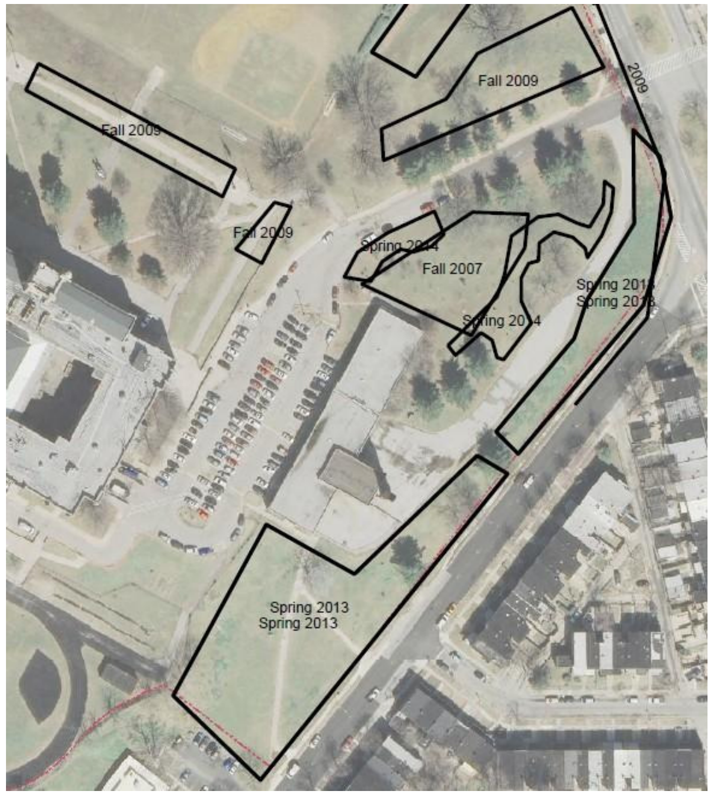

Figure 7

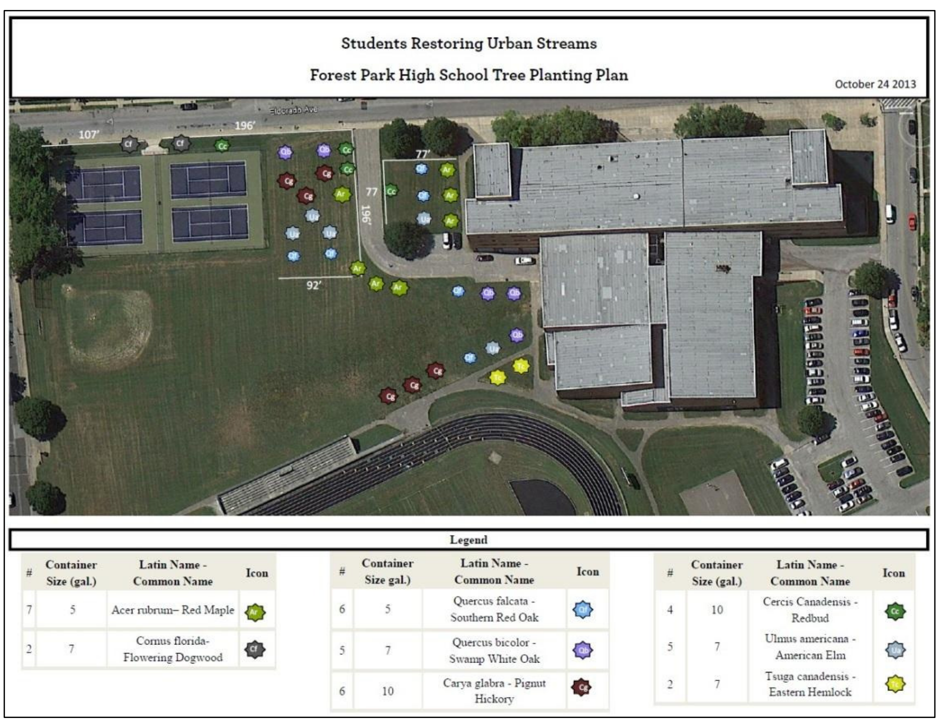

Figure 8

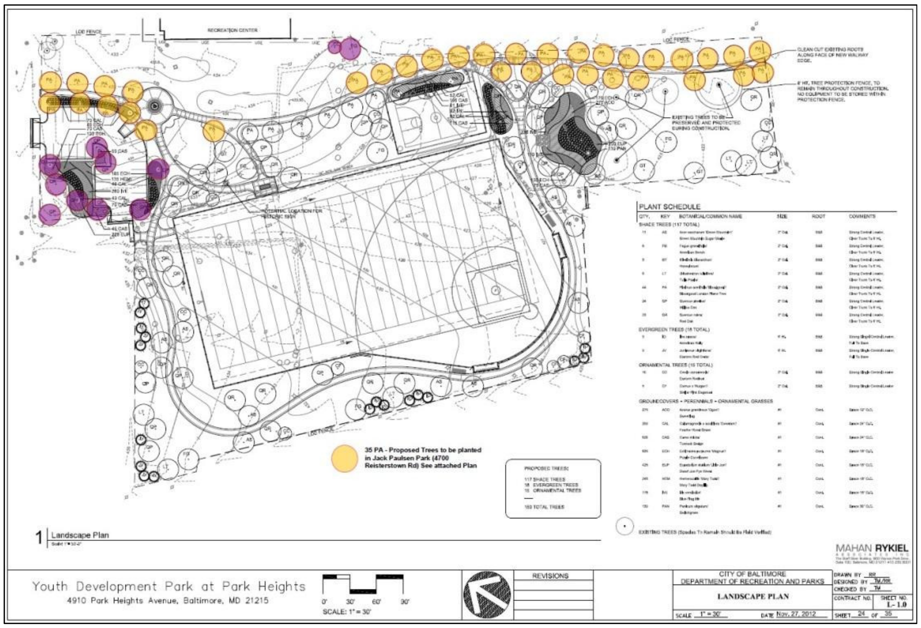

Figure 9

While it would be ideal to have site plans that have been corrected to reflect modifications made at the planting site, it requires additional resources that have not been available to the individual planting organizations.

In 2014, a revised set of TreeBaltimore standard planting reporting forms was released. The new format adopted some of the techniques displayed in the alternate reporting methods, and specified the data that should be collected for each planting and individual tree. The main change was the creation of separate reporting forms for group trees versus individual trees. Several fields were modified or added to the 2012 form to better reflect the necessary information that concerned planting coordinators and forest managers. Both versions of the form contain the same fields.

Standard Form - Group of Trees (2014)	
Group details	**Tree List**
Planting ID	Quantity
Place Name	Common Name
Place Type	Genus
Street Address	Species
Location Notes	Cultivar
Date Planted	Container
Contact Person	Caliper
Planting Org	Nursery
Labor/Volunteers	Date Delv.
Maintained By	Notes
Program	**Draw planting boundaries in Google Earth**
Notes	

Figure 10

Figure 10 is the outline of the 2014 reporting standard for groups of trees. Each group planting has an individual form that collects pertinent information about that planting, which is shared by all of the trees in that planting. Each group planting also has an accompanying tree list that identifies the specific characteristics of the trees planted in that group. Trees sharing identical characteristics within the same group can be reported as aggregated quantities. Depending on the capabilities of the planting organization, a post planting plan is recommended, or outlines of the planting areas drawn in Google Earth.

Figure 11 is the 2014 reporting standard for individual trees, intended primarily for street trees, or plantings of trees with unique location information.

Figure 12 and 13 show an example of the 2014 reporting standard for group trees.

Figure 14 and 15 show an example of the 2014 reporting standard for individual trees.

Standard Form - Individual Trees (2014)
Project Name
Place Name
Place Type
Street Address
Latitude (if available)
Longitude (if available)
Location Notes
Quantity
Common Name
Genus
Species
Cultivar
Container
Caliper
Nursery
Date Delv.
Date Planted
Planting Org
Labor/Volunteers
Contact Person
Maintained By
Program
Notes

Figure 11

Event Details for Group Plantings. List trees on next worksheet.			
Group Planting	**Planting 1**	**Planting 2**	**Planting 3**
Place Name	Northwest HS	New Cathedral Cemetery	Druid Hill Park
Place Type	School	Cemetery	Park
Street Address		4300 Old Frederick Rd	2700 Madison Ave
Location Notes			
Date Planted	4/24/2014	5/2/2015	4/12/2013
Contact Person	Debra Lenik	Sam Little	Mark Cameron
Planting Org	Blue Water Baltimore	Parks & People	DPW
Labor/Volunteers	Northwest Students	Edmondson neighborhood org	Lorenz, Inc.
Maintained By	Blue Water Baltimore	Parks & People	Lorenz, Inc.
Program	SRUS		
Notes	Standing water on site		

figure 12

Tree Lists for Group Plantings. Enter event details on previous worksheet.												
Group planting events												
Planting 1	**Planting 2**	**Planting 3**										
Quantity			**Total**	**Common Name**	**Genus**	**Species**	**Cultivar**	**Container**	**Caliper**	**Nursery**	**Date Delv.**	**Notes**
10	**5**	**5**	**20**	Armstrong Maple	Acer	x freemanii	Armstrong	#20 container		Chemin	2/12/2014	
	5	**1**	**6**	Red Maple	Acer	rubrum		#15 container		Chemin	2/12/2014	
3	**7**		**10**	Tulip Poplar	Liriodendron	tulipifera		B&B	1.5"	HRN	9/24/2013	
2		**5**	**7**	Apple	Malus	domestica		bare root		HRN	2/28/2014	

figure 13

Location Information				**Tree Information**								
Project Name	**Place Type**	**Street Address**	**Location Notes**	**Quantity**	**Common Name**	**Genus**	**Species**	**Cultivar**	**Container**	**Caliper**	**Nursery**	**Date Delv.**
Old Goucher Street Trees	Street	2100 N Charles St	side of	1	American Sycamore	Platanus	occidentalis		B&B	1.5"		
Alameda corridor	Median	3301 The Alameda	opposite	1	Zelkova	Zelkova	serrata		#20 container			
Hampden Street Trees	Street	839 W Powers St		1	Red Maple	Acer	rubrum		B&B	2"		

figure 14

Planting Information						
Date Planted	**Planting Org**	**Labor/Volunteers**	**Contact Person**	**Maintained By**	**Program**	**Notes**
4/4/2015	BWB	Old Goucher Association	Debra Lenik	BWB	SRUS	Soil seems compacted
4/6/2015	BCRP Forestry	Lorentz	Jahmilla Wilson	Lorentz		
4/14/2015	PPF	Hampden Community Council	John Tracy	P&P		Poor health at planting

figure 15

VITA

Victor Gabriel Miranda was born in in Manchester, Connecticut, USA, on September 24, 1982, and lived in Louisville, Kentucky, from 1983 until 1999, where he attended elementary through high school. He attended Ohio State University in Columbus, Ohio, and Towson University in Towson, Maryland, where he graduated in 2006 with a Bachelor of Science in Applied Geography, specialized in Geographical Information Systems. In 2010 he received an Erasmus Mundus Fellowship to pursue a Master of Science in Mediterranean Forestry and Natural Resources Management at the University of Lisbon and the University of Valladolid, graduating in 2015. Victor has worked for over six years with private contractors for Rockville County and Baltimore City in the divisions of Parks and Transportation, where he uses his GIS skills and knowledge of urban forestry. He currently lives in Baltimore, enjoys gardening and outdoor sports, and loves nature.