Mortality in the urban forest: a comparative analysis of tree survival in West Oakland with respect to planting entity

Katerina Morici

Abstract Urban forestry is the practice of managing trees in urbanized landscapes for the benefit of the surrounding human population. Trees are an essential component of urban areas all over the world. The economic, environmental, social, and psychological advantages of establishing and maintaining healthy urban trees are well established. However, due to the difficulty of gathering long-term data in the heterogeneous urban landscape, little is known about the processes which regulate tree planting success. This study is a comparison of mortality between two different planting agencies: the City of Oakland and Urban Releaf, a nonprofit community-based organization, to determine if trees planted by a community organization had a greater survival rate. Two tree inventories with a one-year time lapse were completed of 1108 trees in West Oakland. The results were inconclusive regarding the role that planting entity plays in tree mortality due to inherent variation in study site, tree species, and size class. Trees with smaller diameters were found to display significantly higher mortality. Variation due to species and land use was also established as a source of significantly different mortality rates. Understanding the principal factors in tree mortality may help forest managers determine how to efficiently allocate funds to maintain a healthy and viable urban forest.

Introduction

Street trees provide a broad range of benefits that include improved economic, ecological, human health, and community conditions (Dwyer *et al.* 1992). A well-maintained urban forest is a financial asset for a community. Urban greening has been proven to increase the surrounding property values (Tryvainen 1997, Anderson & Cordell 1985). This indicates that trees are a desirable feature of the urban landscape. An analysis of the cost-benefit ratio of the urban forest in Modesto, California revealed that benefits exceed management costs by a factor of two to one (McPherson 1999).

The ecological and environmental benefits that trees provide are accumulated over their lifespan. An Australian study of 400,000 trees planted over the last 100 years estimated the monetary contribution due to energy savings, carbon sequestration, and pollution mitigation to be between $20 and $67 million during a four-year period (Brack 2002). A recent study of five US cities demonstrated that, per year, each dollar spent on maintaining the urban forest has an estimated return of $1.37 to $3.09 in storm water control, temperature reduction, and air quality improvement (McPherson *et al.* 2005). In addition, tree shade lowers both asphalt and ambient air temperature, which reduces the need for air conditioning and decreases pavement distress (Asaeda 1996, McPherson and Muchnick 2005). It is apparent that urban trees serve functions far more varied than improving streetscape aesthetics.

Trees have also been shown to augment physical and psychological health. For example, Ulrich (1984) demonstrated that hospital patients with a tree view had shorter stays, used less medication, and had better rapport with the nurses than patients in the same condition that had a view of a brick wall. Likewise, people suffering from depression experienced increased health and well-being after volunteering at a local tree management organization (Townsend 2006).

Caring for urban trees fosters a sense of community and connection with nature (Austin 2002). This is especially important in economically disadvantaged neighborhoods for several reasons. First, public open space is limited in multicultural, economically disadvantaged areas (Johnson & Shimada 2005). Second, urban greening may provide a forum for community interaction and participation. Third, it is more cost-effective to maintain existing trees in a healthy state than replacing dead trees.

For all the benefits they provide, street trees face a number of challenges associated with living in an urban environment. Stresses due to vandalism, cars, poor air quality, restricted growing space, and contaminated urban soil decrease a tree's ability to cope with naturally-occurring stresses, such as insects, disease and drought. Mortality due to vandalism is unusually high in areas of lower socioeconomic status (Nowak *et. al* 1990). In a study conducted in Berkeley and Oakland, tree death two years after planting was not significantly correlated with species, but was related to socio-economic status of the surrounding neighborhood (Nowak *et al.* 1990). Vandalism was reported to be a recurring cause of mortality. In a survey of European cities and towns, up to 30% of newly planted trees were affected by vandalism (Pauleit 2002). It is clear that human-induced damage to urban trees is a common problem. However, it has been demonstrated that a reduction in the incidence of injury to trees due to vandalism is correlated with increased community participation and direct contact with individuals (Cole 1979, Gobster & Dickhut 1995).

While the psychological, social, and environmental benefits of trees in urban settings have been clearly established, there are few authoritative studies regarding the survival rates of city trees. In this study I investigate whether trees planted and maintained by a community organization exhibit significantly different mortality rates than trees planted and maintained by the city.

In order to gauge the effect of community involvement in tree survival, I investigate the efforts of Urban Releaf, a local nonprofit organization that focuses on employing youth to plant trees in economically disadvantaged areas of Oakland and Richmond. The goal of this organization is "to revitalize these communities by planting trees, providing environmental awareness education, and providing on-the job training to disadvantaged and at-risk youth" (www.urbanreleaf.org). The two main planting entities in the West Oakland I consider in this study are Urban Releaf and the City of Oakland. Trees may also be planted by private property owners, however this was not considered in the present study.

If inner-city planting by Urban Releaf proves to be more successful at reducing vandalism than planting by the City of Oakland, devoting more resources toward community involvement will increase the economic viability of urban forestry. Furthermore, understanding mortality and applying management techniques which maximize the lifespan of urban trees will increase the ability of the urban forest to meet the needs of the surrounding community at a minimal monetary cost.

I expect that trees planted by Urban Releaf will have lower mortality than trees planted by the city. Since vandalism is a major cause of tree mortality (Nowak *et. al* 1990), involving the neighborhood or community in which the trees are planted is likely to have a positive impact on survival. Similarly, Sklar and Ames (1985) concluded that including the population of an area in the planting and maintenance process decreases tree mortality.

In collaboration with a UC Berkeley urban forestry graduate student, Lara Roman, a survey of approximately 1,200 trees in West Oakland was completed in October 2007. These trees were initially inventoried in 2006 by a research team from UC Davis. For my project, I compared one year survival rates for trees of the same species and in the same size class that were planted by both Urban Releaf and the City of Oakland. Understanding what factors are liable to increase mortality and encouraging a dialogue between urban forestry directors may help manage the urban landscape more efficiently.

Methods

To gauge the effect of planting agency on tree mortality, a study with a time lapse of one year was conducted in a 4.7 km^2 area in West Oakland, California. The study area is bounded by Martin Luther King Jr. Ave., Peralta St., 35^{th} St., and West Grand Ave (Appendix). Urban Releaf and the City of Oakland have been aggressively planting in this location due to its lack of established urban forest and lower socio-economic status. US census data from 2000 reports that 11-24% of the residents in this area are Caucasian and 15-53% are African American. In parts of West Oakland, the percentage of families living below the poverty line is almost triple the national average. The percentage of renter-occupied housing for the majority of the study site is more than twice the national average. Pollution from highways, the Port of Oakland, and some local industries are a cause for environmental and health concerns in the area. To address these concerns and uplift the surrounding community, increased effort has recently been dedicated to urban greening.

Both Urban Releaf and the City of Oakland have planted similar tree species over the same period of time. These trees are dispersed unsystematically over residential and industrial areas. Since its founding in 1998, Urban Releaf has planted over 12,000 total trees in Oakland and Richmond, CA. The City of Oakland Department of Public Works maintains about 38,400 total trees within the entire city.

A research team from UC Davis performed a complete inventory of all street trees within the study area in the summer of 2006 (Xiao *et al*. 2007). They recorded tree species, diameter at breast height (DBH), height, latitude-longitude coordinates, side of street, condition of the wood, condition of the leaves, planting entity, land use, site conditions, and recommended maintenance. From September to October 2007 we conducted a second complete census for the purpose of discerning trends in tree mortality. Using GIS maps of city blocks with tree ID number and exact location, we located the trees and recorded their current state (alive, dead, or gone). Since early leaf drop is common in trees that are stressed but not dead, the threshold of death is subjective. We concluded that the most concrete method of determining mortality is presence (includes trees listed as alive and dead) versus absence (includes trees listed as gone). Similar methods were used in determining tree mortality rates in the Baltimore, Maryland study conducted by Nowak *et al.* (2004).

I used chi-square analysis via contingency tables to uncover any predisposing factors and statistically significant trends between tree mortality and planting entity, DBH size class, land use, and health rating based on leaf condition. Analysis involving species employed the Fisher's exact 2-sided test due to the reduced sample sizes. Odds ratios are reported where significant P-values were calculated. Significance between two variables is denoted by assigning the same letter to each variable.

Planting entity, size class, and species were the principal risk factors under consideration for mortality. Trees of the same genus or species and in the same DBH size class were compared for each planting entity. Of the 150 total street tree species in the study area, three species/genera have been planted in approximately the same time period by both entities: *Magnolia grandiflora*, *Prunus cerasifera*, and *Pyrus* sp. (Table 5). The similar tree size and distribution allows for a meaningful comparison of tree mortality between the nonprofit and municipal planting programs. Trees in the same genus that are known to tolerate similar environmental conditions (such as *Pyrus kawakamii* and *Pyrus calleryana*) are grouped together to increase sample size. However, in a more varied genus, such as *Quercus*, no such grouping is made. The impact of land use on mortality will also be tested. The overall purpose of this analysis is to examine whether the entity that plants and maintains urban trees has an influence on mortality, as well as to explore potentially confounding factors.

Results

Overall Tree mortality from 2006-2007 in West Oakland was found to be 8.2%. Of the 1108 street trees inventoried in 2006, 249 were planted by Urban Releaf, 624 were planted by the City of Oakland, and the remaining trees were planted privately or by an unrecorded entity (Figure 1).

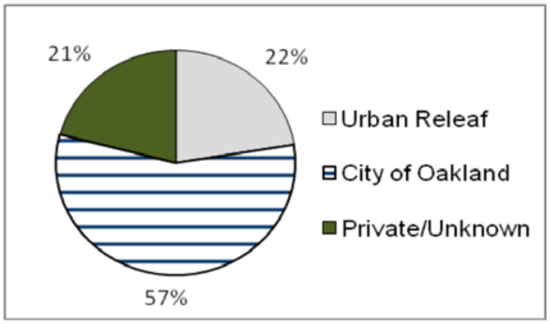

Figure 1: Percent of all trees in West Oakland by planting entity in 2006.

While conducting the 2007 inventory of the study area, we encountered several issues with the original database. Some of the trees recorded in the original database were found to be duplicates. Where two trees of the same size, species, and exact location were listed and only one tree or planting area existed, one entry was assumed to be a duplicate and was deleted. In other cases, trees that had been planted prior to 2006 were not included in the database. These trees were recorded for future monitoring. They were not included in this study due to our inability to account for omitted trees which had been removed during the past year.

Single factor analysis In the study area, the City of Oakland has planted over twice as many trees as Urban Releaf (Figure 2). Trees planted by Urban Releaf were 3.8 times more likely to be removed during the course of one year than trees planted by the City of Oakland (Table 1).

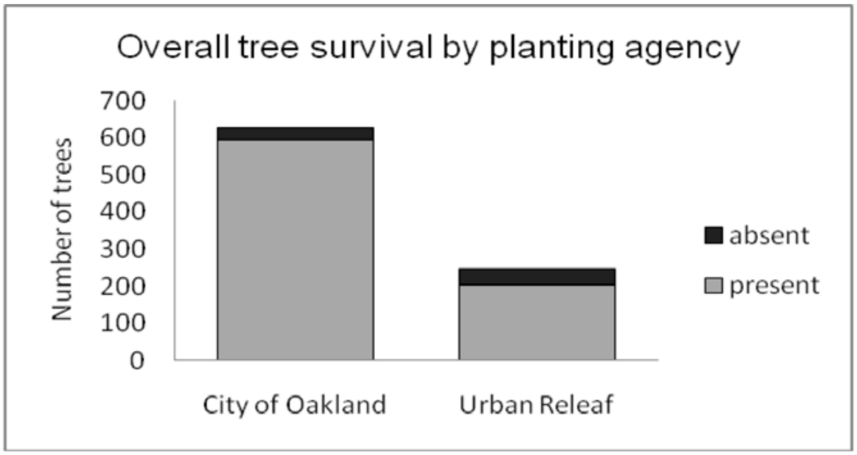

Figure 2: Number of trees planted by the City of Oakland and Urban Releaf, including one-year survival data.

Table 1: Planting entity and mortality from 2006-2007 in West Oakland.

Planting entity	Percent mortality	Total number	OR	P-value
Urban Releaf	17.7	248	3.8	<.0001
City of Oakland	5.4	628		

Overall trends show that trees <7.6cm DBH had the highest percentage of mortality (Table 2). A linear regression using 4 DBH size classes shows that 76% of the variation in mortality can be explained by tree size (Figure 3). Significant difference was found between many of the species/genera that were analyzed for variation in mortality (Table 3). Only species/genera totaling 50 or more trees were included to ensure sufficient sample sizes. The data from trees planted privately or by unrecorded entities was included as part of overall survival analysis, but not for comparisons between planting agencies.

Table 2: Mortality by DBH size class in West Oakland between 2006-2007. (X^2 trend: P<0.001)

Size class (cm)	Percent mortality	Total number
<7.6	12.6	604
7.6-15.2	3.3	180
15.2-30.5	4.4	158
>30.5	0.6	154

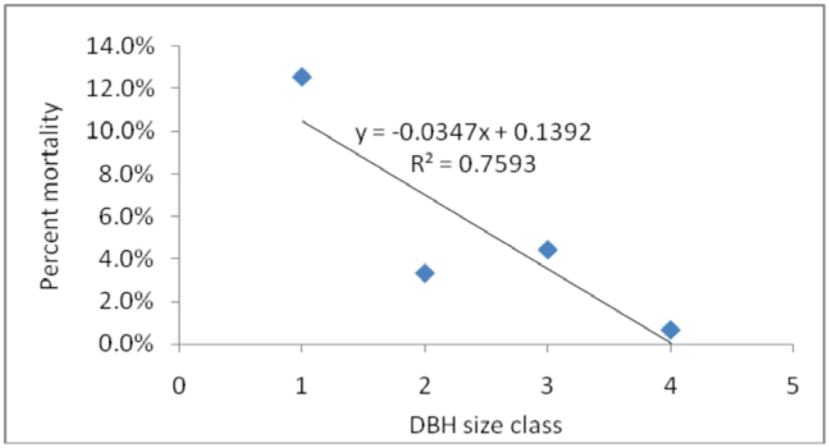

Figure 3: DBH size class and percent mortality in West Oakland from 2006-2007. 1=(<7.6cm), 2=(7.6-15.2), 3=(15.2-30.5), 4=(>30.5)

Table 3: Mortality in West Oakland from 2006-2007 of 5 most numerous species/genera.

Species	Percent mortality	Total number	Significance
Cercis canadensis	21.6	51	abcd
Magnolia grandiflora	7.5	107	be
Prunus cerasifera	6.2	113	df
Pryus sp.	5.3	152	c
Platanus X acerfolia	1.3	158	aef

Analysis of combined factors Mortality in trees less than 7.6cm DBH was significantly correlated with planting agency (Figure 4, Table 4). Small diameter trees planted by Urban Releaf were 2.7 times more likely to die than those planted by the City of Oakland. Larger size classes did not have comparable sample sizes for both planting entities, consequently no trends were found.

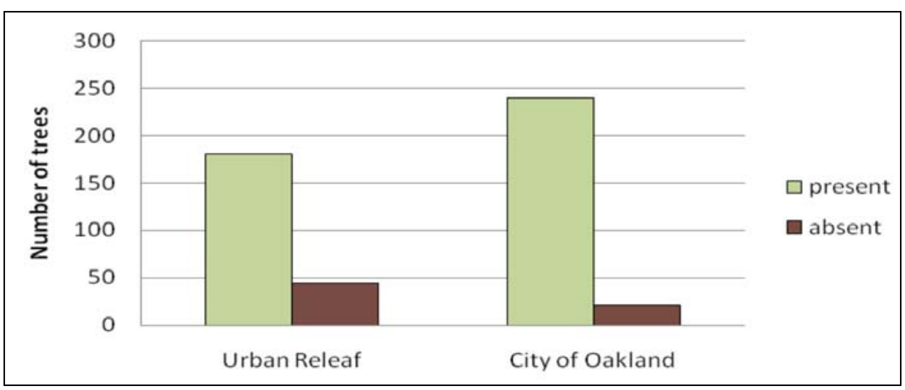

Figure 4: State of trees in the smallest diameter class (<7.6 cm) after one year, separated by planting entity. Data collected in West Oakland from 2006-2007.

Table 4: Mortality between 2006-2007 in West Oakland by DBH size class and planting entity.

Size class	Planting entity	Percent mortality	Total number	OR	P-value
<7.6cm	Urban Releaf	19.6	225	2.7	<0.001
	City of Oakland	8.4	262		
7.6-15.2cm	Urban Releaf	0.0	14		1
	City of Oakland	3.6	112		
>15.2cm	Urban Releaf	0.0	9		1
	City of Oakland	3.1	254		

No significant trends between mortality and planting entity were found after stratifying the data by size class and species/genera (Table 5). Only two species and one genus of the smallest size class were planted in adequate numbers by both entities to make this a viable comparison.

Table 5: Tree mortality in the smallest DBH size class (<7.6cm) stratified by species/genera and planting entity in West Oakland from 2006-2007.

Species/genera	Planting entity	Percent mortality (<7.6 cm)	Total number (<7.6 cm)	P-value
Prunus cerasifera	Urban Releaf	7.1	42	0.344
	City of Oakland	2.2	45	
Magnolia grandiflora	Urban Releaf	22.2	18	0.23
	City of Oakland	10.3	32	
Pyrus sp.	Urban Releaf	18.8	16	0.35
	City of Oakland	8.2	49	

Other factors Mortality was significantly correlated with land use (Table 6). Parks and vacant lots had the highest rate of mortality, followed by multi-family residential areas. Trees planted in industrial, institutional, or large commercial areas displayed the lowest rate of mortality. The coefficient of correlation between the percent of mortality in different land use categories was .96 (Figure 5).

Table 6: Mortality from 2006-2007 in West Oakland by land use type. (Overall X^2: P = 0.003)

Land use type	Percent mortality	Total number	Significance
park/vacant/other	13.8	58	a
multi-family residential	12	284	bc
small commercial	10.7	149	d
single family residential	6.4	267	c
industrial/institutional/commercial	4.6	350	abd

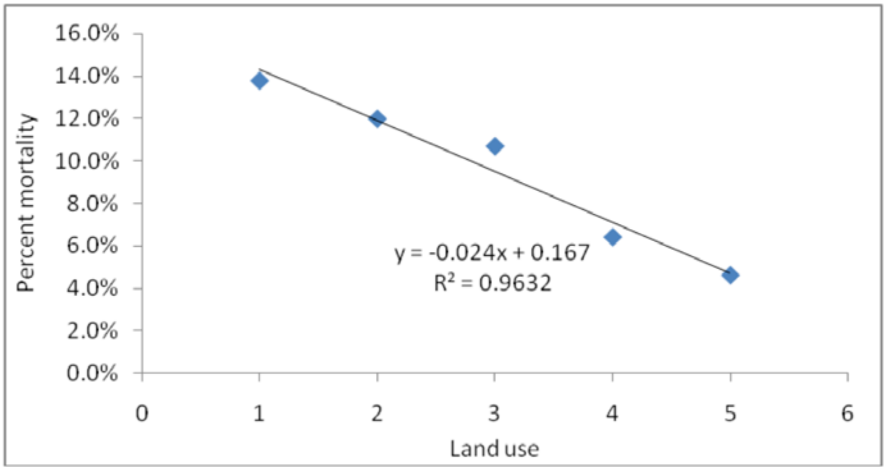

Figure 5: Correlation between percent mortaliy and land use in West Oakland from 2006-2007. 1=park/vacant/other, 2=multi-family residential, 3=small commercial, 4=single family residential, 5=industrial/institutional/commercial

Discussion

Mortality in the urban forest is related to a number of factors; therefore attributing tree survival rates to planting agency is not a straightforward task. The City of Oakland was planting trees decades before Urban Releaf. Given that larger, more established trees have higher rates of survival, it is not meaningful to compare the overall mortality for all trees planted by the two organizations. A significantly higher mortality rate was detected in the one-year survival rate of saplings (<7.6cm DBH) planted by Urban Releaf compared to those planted by the City of Oakland (Table 4). Since mortality has been previously shown to differ between tree species and the planting lists of both organizations are not identical (Nowak et al. 2004), it is premature to consider the difference in overall sapling mortality to be the direct result of the actions of the organizations.

The five most numerous tree species/genera displayed statistically significant differences of one-year survival (Table 3). *Platanus X acerfolia* had the highest survival rate, but the population tended to be comprised of large, established trees. This may contribute to a falsely low mortality rate compared to smaller trees of other species.

Sapling mortality rates did not significantly differ between agencies when comparisons were made by size class and genera/species (Table 5). All instances with meaningful sample sizes showed no significant correlation between mortality and planting entity. This indicates that the difference found in overall tree mortality between Urban Releaf and the City of Oakland may be related to choice of species and length of time each has been an active planting entity.

Land use type strongly corresponded to mortality rate. Parks and vacant lots were the least likely places for trees to survive (Table 6). A possible explanation for the elevated mortality rate is that open space areas are heavily used, but no person assumes the trees' protection. This is supported by the comparatively low death rate of street trees adjacent to single family homes. Industrial, institutional, and large commercial areas comprised the only land use category which exhibited a higher survival rate than single family residences. This category included several schools with older trees, which may have skewed the results toward a lower mortality rate.

Previous studies suggest that community involvement in tree planting and maintenance may reduce vandalism and augment street tree survival (Cole 1979, Gobster & Dickhut 1995, Sklar and Ames 1985). The results of this study neither supported nor refuted this hypothesis. Due to the nature of the study, there was no method to track the incidence of vandalism.

The level of involvement between a community organization and resident is likely to impact the resident's behavior toward tree care. A highly involved community non-profit has the capability to increase resident knowledge. Additionally, a local movement centered on urban greening may heighten sense of pride and ownership of neighboring trees. Urban Releaf employs local youth and volunteers, but does not typically incorporate the adjacent house's residents in street tree plantings. Since both the City of Oakland and Urban Releaf plant in the same area, residents probably do not distinguish one agency's trees from the other. A survey of the residents would be informative and provide useful insight into community behaviors and perceptions, but is beyond the scope of this project.

Tree species, size class, and land use have been shown to significantly impact tree mortality (Nowak et al. 2004). In traditional forestry, these factors could be equalized by using patch analysis to understand causes of urban tree mortality (Zipperer et al. 1997). Ecological patterns are most recognizable when an area is divided and examined according to history, stand composition, land use, and management goals (Zipperer et al. 1997). In the urban forest, street trees have a similar set of management objectives. However, identifying patches based on age or size and land use may prove to be useful. Either a study of several species in a homogenous area or a more extensive inventory (including vegetation age, structure, and management plan) would be necessary to generate an appropriate sample size for patch analysis. Controlling variation in major stand dynamics would allow for an accurate quantification of the importance that other factors, such as planting entity, play in urban tree mortality.

In conclusion, this study did not find a clear link between planting agency and tree mortality. It is possible that the difference in mortality was not detected by this study due to small sample size and heterogeneous environment. Another deduction is that planting organization has far less impact on survival in the urban forest than other factors, such as specie, size, and land use. This inference is supported by the study results, which found that small diameter trees are more vulnerable to mortality than large established trees. The species examined displayed differing survival rates. Additionally, trees planted in heavily used open space tended to die at higher rates than trees in other land use areas. The processes that lead to tree death deserve further exploration in order to maximize efficient management of urban forests.

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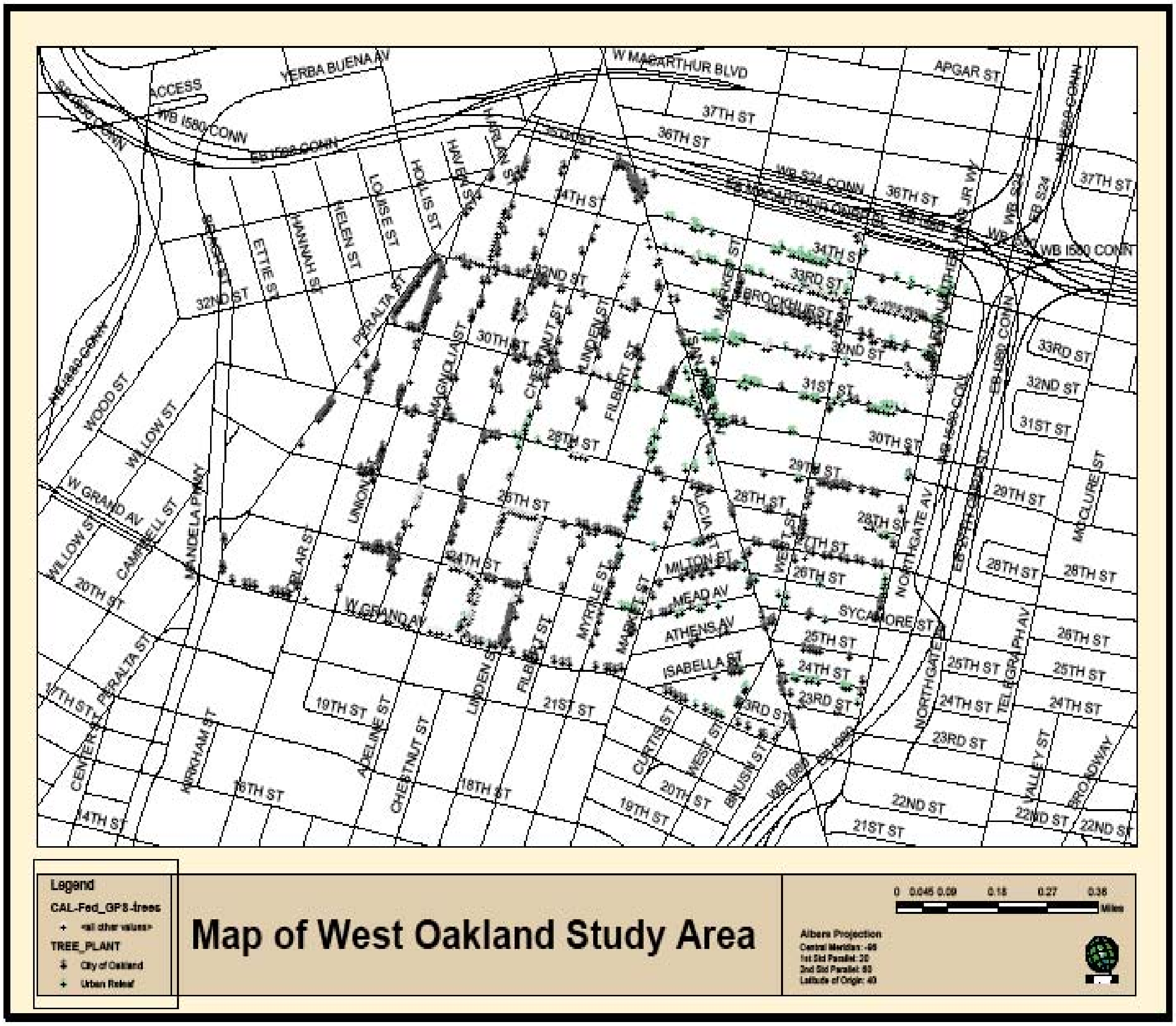
Appendix


Map of West Oakland Study Area
Legend
CAL-Fed_GPS-trees
TREE_PLANT
City of Oakland
Urban Releaf
Albers Projection
Miles
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YERBA BUENA AV
APGAR ST
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