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Low Income Urban Forestry Program in Tucson, Arizona, USA

Tucson is located in the Sonoran Desert, 117 km north of the US-Mexico border. The borderland region is an area experiencing increased temperatures and changing precipitation patterns caused by the combustion of greenhouse gases. Planting drought-tolerant trees to provide cooling shade has been an important mitigation strategy for Tucson and other arid cities. From 2007 to 2013, the Sonora Environmental Research Institute, Inc. (SERI) collaborated with Trees for Tucson (TFT) to distribute drought-resistant trees to low income families in south metropolitan Tucson. The Pima Association of Governments has found that this area has significantly less green spaces than other areas of Tucson. SERI conducted an extensive bilingual community outreach to recruit families, and presented tree stewardship information to families in both English and Spanish. Chilean mesquite (*Prosopis chilensis* and *Prosopis chilensis* hybrid), red push pistache (*Atlantica X Integerrima*), and blue palo verde (*Parkinsonia florida*) had the highest survival rates while willow acacia (*Acacia salicina*) and sweet acacia (*Acacia farnesiana*) had the lowest survival rates. *Acacia salicina* is less cold tolerant, and a severe frost in February of 2011 may have contributed to its higher mortality.

Keywords
urban forestry, street trees, mortality, stewardship, arid cities

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INTRODUCTION

The combustion of fossil fuels such as coal and petroleum has released an excess of carbon dioxide into the atmosphere, causing the average global surface air temperature to increase by about 1.0°C over the past 115 years. Even under the most optimistic greenhouse gas emissions scenario, the average global temperature is projected to rise at least another 1.6°C for the period 2021–2050, relative to the average from 1976–2005 (USGCRP 2017). In the American southwest, higher temperatures are predicted to cause increased evaporation of soil moisture, which in some areas may not be offset by increased precipitation (Cook et al. 2015).

Rising temperatures are predicted to intensify the urban heat island effect (Maxwell et al. 2018), which is defined as the temperature difference between an urban area and the surrounding rural areas (Chow et al. 2011; Comrie 2000). Urban areas are warmer because impervious surfaces such as asphalt, concrete, and rooftops absorb more solar energy than natural vegetation and agricultural land. Heat released by industrial processes, interior building cooling, and transportation also release heat into the atmosphere (Wilby 2003). The temperature difference is often greatest at night, when heat stored in urban surfaces during the day is released to the atmosphere. The minimum temperatures in Phoenix and Tucson are on average 3.88°C and 1.38°C, respectively, warmer than the surrounding rural areas (Brazel et al. 2007). As cities expand their boundaries and increase in population, the urban heat island effect is predicted to intensify (USGCRP 2017).

In the face of rising temperatures, planting trees and other vegetation in urban areas has become a recommended cooling strategy (Jenerette et al. 2011; Chow et al. 2011; McPherson 2014). Trees provide other benefits such as carbon sequestration, noise reduction, and air pollution reduction through the dry deposition of the pollutants onto the leaves (McPherson et al. 2005; McPherson 2014; Dwyer et al. 1992). Trees intercept rainfall before it reaches the ground, thereby attenuating the amount of stormwater that reaches the municipal sewer system and reducing the potential of flooding (McPherson et al. 2005; Berland and Hopton 2014; Dwyer et al. 1992). Urban forests improve the esthetics of the urban environment, and make the urban environment a more pleasant for people to work, live, and spend leisure time. Trees also reduce stress and improve the physical health of residents (Dwyer et al. 1992).

To enjoy the many benefits of urban forests in a cost-effective manner, it is essential for cities to properly plan for climate change mitigation as well as other present and future needs (Dwyer et al. 1992). In arid cities such as Phoenix and Tucson, maintaining a healthy urban forest is challenging because of the need for water conservation (Gober et al. 2009; Chow et al. 2011). Replacing lush non-native vegetation with a xeric landscape of rocks, cacti, and decomposed granite is insufficient, because the exposed ground will emit more infrared energy and increase the need for interior cooling (McPherson et al. 1989). To conserve water while minimizing the need for increased cooling energy, water-loving tree species need to be replaced with drought and heat tolerant tree species that are adapted to the arid climate.

To obtain cooling shade and other benefits of an urban forest, the Sonora Environmental Research Institute, Inc. (SERI) and Trees for Tucson (TFT) have been providing drought and heat tolerant trees to Tucson families since 2007. TFT is a program of Tucson Clean & Beautiful, Inc. The focus of this urban forestry project is southern metropolitan Tucson, a low-income population that has been underserved by existing programs and which has fewer resources to purchase and maintain trees. This paper evaluates the survival rate of the trees planted through the SERI/TFT program from 2007 to 2013. Documenting the tree survival rate in an arid climate will provide useful information for modeling the future benefits of these trees in terms of carbon dioxide stored and energy saved (McPherson 2014).

RESEARCH METHODS

A geographic information system (GIS) analysis of the Pima County official parcel database shows that the overall average lot size in Tucson is 0.77 acres, or roughly 0.5 acres if larger industrial parcels are eliminated from the average. The 2018 population of Tucson is 545, 975, a 3.7% increase from the 2010 census population of 526,635. The 2013-2017 median household income is $39,617 (in 2017 dollars), and 24.1% of Tucson residents live in poverty (US_Census_Bureau 2019). Overall, the southern portion of the city has a higher population than northern Tucson, but higher population census tracts can also be found in the northern portion of the city (Figure 1a). A higher poverty rate is found on the northwest and southwest sides of the city (Figure 1b), and this pattern is similar to the percentage of residents attaining a high school diploma (Figure 1c). A higher concentration of foreign-born residents are found near the center of the city (Figure 1d).

Bioclimatic Characteristics

Tucson, Arizona is located in the Sonoran Desert 117 km north of the US-Mexican border, in a basin surrounded by four mountain ranges. Annual Tucson precipitation (1981-2010 average) ranges from 11.3 inches (287.0 mm) at the University of Arizona to 12.01 inches (305.1 mm) at the University of Arizona Agricultural Center. The average annual precipitation of 11.59 inches (294.4 mm) at the Tucson International Airport falls between these two values (National Weather Service (NWS) 2019). Most of the precipitation occurs during two rainy seasons: westerly frontal systems from November through March, and the North American Monsoon in July and August (Weiss et al. 2009). The occurrence of freezing temperatures is an integral part of the Sonoran Desert climate (Weiss and Overpeck 2005), making it necessary to select trees species for Tucson that are cold tolerant. A catastrophic freeze, which Bowers (1980) defines as a minimum temperature between $-8.3^{o}C$ and $-5.6^{o}C$ that lasts for 15 to 20 hours, can cause widespread frost damage to Sonoran Desert plants and the Tucson urban forest. The Tucson area experienced four catastrophic freezes between 1946 to 1979. Between 1979 and 2011, there were no freeze events meeting these criteria until 2 and 3 of February 2011 (Orum et al. 2016).

Much of the mesa upon which Tucson was built contains caliche, a shallow layer of soil or sediment in which the particles are cemented together by calcium carbonate. Caliche forms a hard, impervious surface that makes planting trees difficult and hinders the downward filtration of water. Caliche is formed when water containing carbon dioxide dissolves calcium carbonate in the soil to form a cement-like material. Caliche is common in arid lands around the world, and the water source may be either underground water or precipitation. Caliche may even form when a lawn is watered (Breazeale and Smith 1930).

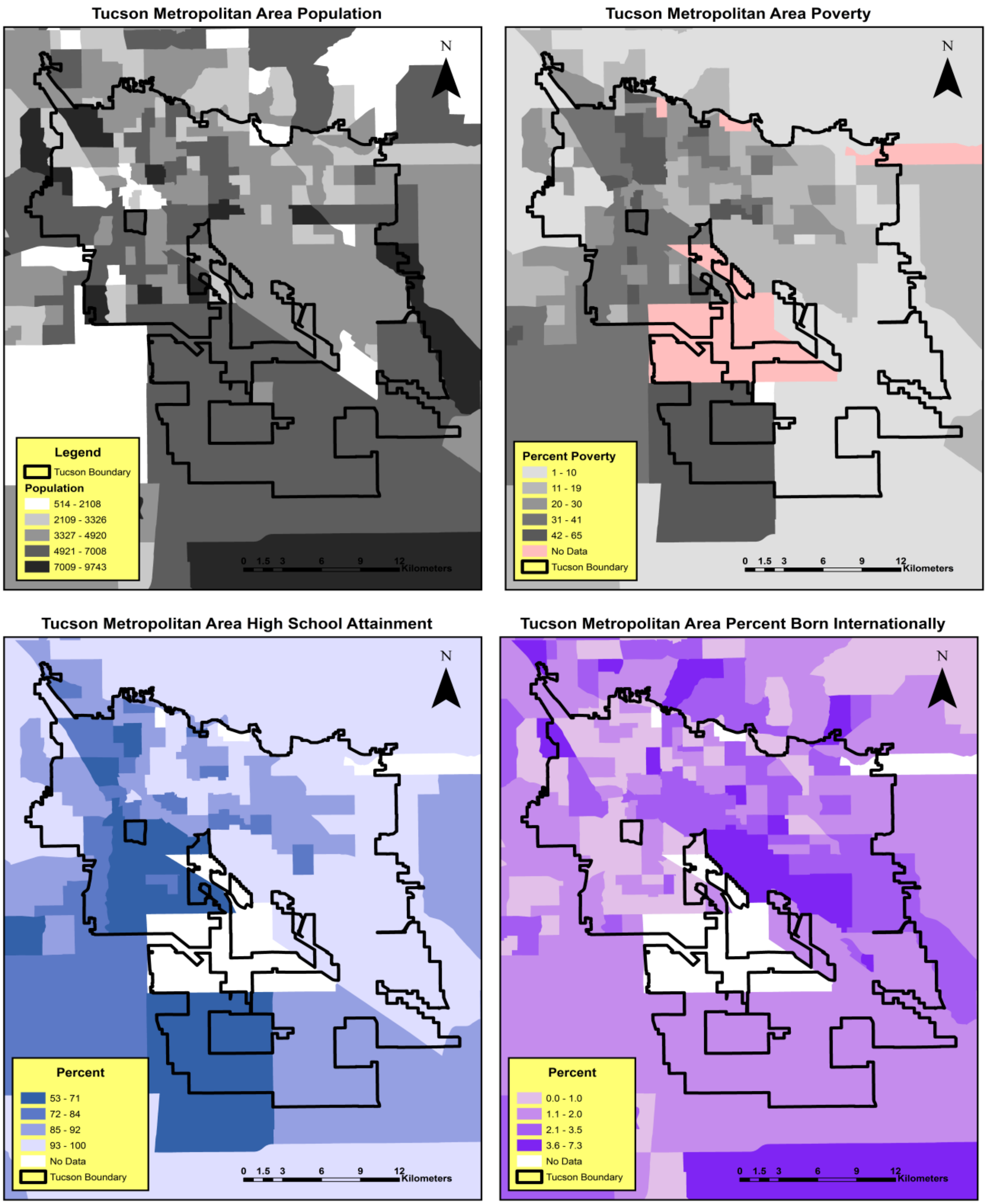

Figure 1: Tucson demographics by census tract: a) population; b) poverty; c) high school attainment; and d) percent of residents born outside the country. Data from the US Census Bureau American Factfinder web page and Pima County.

In the past, many non-native plant species requiring a lot of water were planted in Tucson. When the railroad reached Tucson in 1880, new residents began their effort to transform the desert landscape into a garden oasis by creating lawns using Bermuda grass (*Cynodon dactylon*) and winter rye (*Lolium sp*.). Civic leaders mounted a citywide brush and tree planting campaign with non-native bush species such as oleander (*Nerium oleander*) and roses (*Rosa sp*.). Popular non-native tree species included chinaberry (*Melia azedarach*); eucalyptus (*Eucalyptus* sp.); allepo pines (*Pinus halepensis*) and mulberry (*Morus alba*). As water becomes increasingly scarce, substituting non-native vegetation with drought-tolerant species is now essential for conserving water (McPherson and Haip 1989).

Tree Planting Program

The mission of SERI is to protect the environment and improve community health through partnerships with low-income and minority communities throughout the southwest. SERI conducts community participatory research on environmental sustainability; U.S Department of Housing and Urban Development (HUD) Healthy Homes audits (HUD 2019); and other educational and outreach programs. Of the 4,000 families SERI has visited, over 92% of them prefer to speak Spanish. Consequently, southern metropolitan Tucson has been underserved by traditional English language outreach programs. Since 2007, SERI has partnered with TFT to provide arid-adapted trees for low-income families in sections of the Tucson metropolitan area that have a lower percent tree canopy (Figure 2).

To recruit families for the SERI/TFT tree planting program, bilingual SERI staff set up tables at health fairs and school outreach programs; walked neighborhoods to distribute information; conducted home visits; and gave presentations to community and parent groups in both English and Spanish. SERI also mailed information on tree care and rainwater harvesting workshops to homeowners in its database that were listed as having no trees in their yards (434), or having an interest in rainwater harvesting (352). (SERI compiled this database of families from HUD Healthy Homes inspection reports as well as information from other SERI activities such as distributing smoke alarms.) SERI reached 1,984 families through various outreach activities, of which 1,117 families decided to participate in the program. SERI conducted 352 home visits; 67 workshops; attended 593 community events; conducted 186 neighborhood walks; and mailed information to 786 families.

SERI staff conducted HUD Healthy Homes inspections for each participating family. The Healthy Homes audit includes 29 health hazards such as lead, asbestos, radiation, sanitation, trips/falls, and structural integrity (HUD 2019). During each audit, SERI included a survey of the family's gardening and landscaping experience and found that over 45% of participating families had no trees in their yards. To increase tree survival, SERI required families to attend a two hour, English or Spanish tree stewardship workshop. The workshops, which included both lecture and hands-on instruction, taught families how to care for their new tree and where to plant it to provide maximum shade for their house. SERI also translated developed written materials for Spanish speaking families by translating TFT brochures into Spanish.

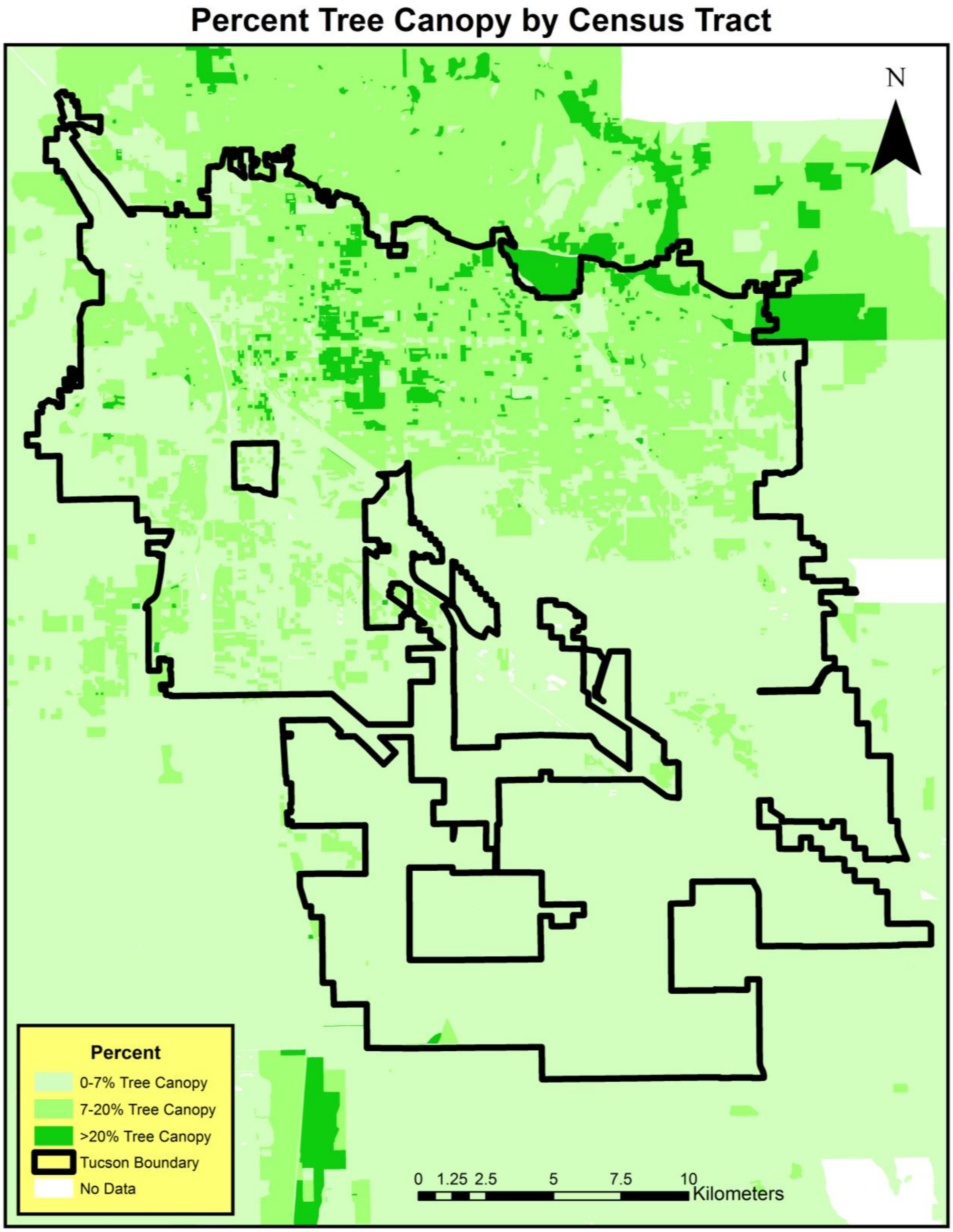

Figure 2: Percentage of tree canopy in Tucson, derived from 2008 LIDAR data. The SERI/TFT project focused on the southern half of the city where there was less greenspace. (Source: Pima Association of Governments).

Evaluating Tree Survival

A variety of tree species were provided through the SERI/TFT program (Table 1). In 2013, SERI staff evaluated tree survival by following up with the 1,117 families who had had received trees through the 2007-2113 program. Trees were evaluated with a subjective scale from 0 to 4, where 0 meant that the tree was dead or had been removed, and 4 meant that the tree was thriving. Including removed trees with dead trees is consistent with the procedures of other tree assessment projects (Roman and Scatena 2011). SERI staff recorded information on why the tree died or was removed, and whether the tree was planted following SERI instructions. In cases where a new family lived in the home and they had no knowledge of the tree, the tree was recorded as “Not Found”. The data and pictures of all located trees were collected on iPads using a Filemaker Pro database, and transferred to a main database for analysis.

Table 1: Tree species distributed through the SERI/TFT program. SERI obtained cold hardiness information from the nursery supplying the trees. Tree cold hardiness is evaluated according to the United States Department of Agriculture (USDA) Plant Hardiness Zone Map, which is created using climate data (Daly et al. 2012).

Tree Species	**Years Distributed**	**Native**	**Cold Hardiness (°C)**
Desert Willow - *Chilopsis linearis*	2007-2013	Yes	−23
Willow Acacia - *Acacia salicina*	2007-2010	No	−7
Sweet Acacia - *Acacia farnesiana*	2011-2012	Yes	−2
Catclaw Acacia - *Acacia greggii*	2012-2013	Yes	−18
Velvet Mesquite - *Prosopis velutina*	2007-2012	Yes	−18
Chilean Mesquite - *Prosopis chilensis* and *Prosopis chilensis hybrid*	2007-2012	No	−12
Blue Palo Verde - *Parkinsonia florida*	2011-2012	Yes	−12
Red Push Pistache - *Atlantica X Integerrima*	2012-2013	No	−18

We analyzed our results with a statistical analysis utilizing Pearson’s Chi-square test for independence, with a significance level of 0.05. For values of 10 or less, a Fisher’s Exact Test for independence was used, assuming a two-sided distribution with a significance level of 0.05 (Milton 1999). The annual survival and mortality rates were calculated using the equations outlined by Roman and Scatena (2011). These equations used assume stationarity, or a constant probability of mortality over time. The annual mortality, m_{annual}, is defined as

$$m_{annual} = 1 - (N_t/N_o)^{1/t} \quad \text{Equation 1}$$

where N_o is the number of trees planted at time t = 0 and N_t is the number of trees alive at time t. The fraction N_t/N_o is the cumulative survivorship from time t = 0 to time t, and is usually written as l_t. Annual survival, l_{annual}, is defined as

$$l_{annual} = (l_t)^{1/t} \text{ or } 1 - m_{annual} \quad \text{Equation 2}$$

RESULTS

SERI distributed a total of 1,430 trees to 1,117 families. In 2013, we were able to contact 94% of the families representing 95% (1,359) of the distributed trees. We confined our analysis to the trees from families that SERI was able to contact, because we were unable to evaluate the condition of the other 71 trees. SERI was able to locate 1,045 or 77% of these trees; 18% (246) could not be located; and families stated that they never received 5% (68) of the trees (Table 2). Because SERI did not track the planting rate, it is possible that some of the missing trees were never planted. Overall 49% of the 1,359 trees were found alive. Of the 1,045 trees evaluated, 33% were thriving, while 36% were dead or had been removed (Table 3). SERI staff evaluated whether each tree was planted following TFT's guidelines, and we found that 93% of the trees were planted correctly for home shading. When SERI staff asked families why they thought their trees had died, families could provide a reason for only 23% of the trees. The three most common reasons families gave were hot weather; the prolonged February 2011 freeze; and too much caliche in the soil.

Table 2: SERI was able to contact 94% of the families who had received trees, which accounted for 1,359 of 1,430 trees. Table 2 summarizes our results by tree species.

	Number of Trees				Percentage		
Tree Species	**Located**	**Not Found**	**Not Received**	**Total**	**Located**	**Not Found**	**Not Received**
Desert Willow	302	87	20	409	74	21	5
Willow Acacia	301	87	16	404	75	21	4
Sweet Acacia	21	6	2	29	72	21	7
Catclaw Acacia	11	2	0	13	85	15	0
Velvet Mesquite	229	37	8	274	84	13	3
Chilean Mesquite	118	21	15	154	77	13	10
Red Push Pistache	42	2	7	51	82	4	14
Blue Palo Verde	21	4	0	25	84	16	0
Total	**1045**	**246**	**68**	**1359**	**77**	**18**	**5**

We found that Chilean mesquite (*Prosopis chilensis* and *Prosopis chilensis* hybrid), red push pistache (*Atlantica X Integerrima)*, and blue palo verde (*Parkinsonia florida*) had the highest survival rates (Table 3). Lower survival rates for the sweet acacia (*Acacia farnesiana)* and willow acacia (*Acacia salicina*) may suggest that these species are less appropriate for Tucson. Willow acacia has less cold hardiness (Table 1) than the other tree species planted in this project, possibly making it less able to withstand the occasional cold winter temperatures that are an integral part of Sonoran desert climatology. While the higher survival rate of the Chilean mesquite may make it suitable for Tucson, anecdotal evidence indicates that the shallow surface roots cause it to be the tree species most frequently blown over during the summer monsoons. Because shallow roots may be caused by shallow watering, deeper watering may lead to a more dispersed root systems and reduce the risk of wind throw.

Table 3: A summary of tree condition. Trees that were not found are included with the dead trees as per Roman and Scatena (2011).

	Tree Condition (number of trees)						Percentage		
Tree Species	**Dead**	**Poor**	**Fair**	**Good**	**Thriving**	**Total**	**Dead**	**Surviving**	**Thriving**
Desert Willow	108	3	38	55	98	302	36	64	32
Willow Acacia	149	4	32	46	70	301	50	50	23
Sweet Acacia	16	2	2	0	1	21	76	24	5
Catclaw Acacia	4	0	1	0	6	11	36	64	55
Velvet Mesquite	72	0	38	52	67	229	31	69	29
Chilean Mesquite	21	0	3	18	76	118	18	82	64
Blue Palo Verde	4	0	2	10	5	21	19	81	24
Red Push Pistache	5	0	8	10	19	42	12	88	45
All Trees	**379**	**9**	**124**	**191**	**342**	**1045**	**36**	**64**	**33**

Mortality and Survival Rates

Trees were planted over a seven-year range, and not all tree species were planted every year. To evaluate annual differences in tree mortality, we used Equation 1 to calculate the mortality rates for every year that a species was planted. The mortality rates by species and year (Table 4) were evaluated with a Chi square analysis at a significance level of 0.05. First we compared the annual mortality rate for the four tree species planted from 2007 to 2010: desert willow, willow acacia, velvet mesquite, and Chilean mesquite. Every year the less cold tolerant willow acacia (see Table 1) had significantly higher mortality than the other three tree species, while the Chilean mesquite had the lowest mortality rate. The mortality rates of the velvet mesquite were somewhat higher than the Chilean mesquite in 2007, 2008, and 2009, but the differences were not statistically significant. In 2011 and 2012, sweet acacia and blue palo verde were also planted, and the sweet acacia had a much higher mortality rate than blue palo verde. In 2011, desert willow had a significantly higher mortality rate than Chilean mesquite and velvet mesquite. Red push pistache and cat claw acacia were first planted in 2012 and 2013; and the red push pistache annual mortality is significantly lower than the rate of all the other tree species. From this detailed analysis, we conclude that Chilean mesquite, red push pistache and blue palo verde will have the lowest replacement rates.

We found a higher mortality rate for the first 3 years after planting. Although not all trees were distributed every year, our annual mortality results (Table 4) suggest that the annual mortality rate is stabilizing after the initial years. The higher annual mortality rates for willow acacia are probably reflective of the effect of the February 2011 freeze event. Urban forest researchers have suggested that the first several years after planting, referred to as the establishment period, have the highest annual mortality rates (Richards 1979; Miller and Miller 1991). Lu et al. (2010) investigated when mortality rates of street tree populations stabilize and found a significant difference in annual survival rates between years 1-2 and 3-6. After year 6, their data suggested that annual survival rates stabilize. Miller and Miller (1991) suggested that a five-year period be allowed before planting success can be realistically evaluated. Watson et al.

(1986) found that a period of four or more years of stress followed transplanting of 5 to 10 cm diameter trees.

Table 4: Annual mortality rates (percent) by the year planted, based upon the year each tree was planted. Equation 1 was used for these calculations.

Tree Species	2007	2008	2009	2010	2011	2012	2013
Desert Willow	8.4	9.5	6.6	5.9	17.8	24.7	26.3
Willow Acacia	10.4	10.8	12	14.9	-	-	-
Velvet Mesquite	7.2	6.7	5.3	6.5	14.9	18.4	-
Chilean Mesquite	1.4	2.4	2.9	6.2	11.5	16.3	-
Red Push Pistache	-	-	-	-	-	4.3	13.3
Sweet Acacia	-	-	-	-	55	36.8	-
Blue Palo Verde	-	-	-	-	5	14.7	0
Catclaw Acacia	-	-	-	-	-	100	30

Survival rates, annual survival rates (Equation 2) and annual mortality rates (Equation 1) were calculated for each year for all species cumulatively (Table 5). Our survival rate ranges from 56-82%. For 2009 or 5 years, it is 67% with an annual mortality rate of 7.7%. Our survival rate at 2010 or 4 years is 71% with an annual mortality rate of 8.2% and at 2012 or 2 years, 64% and 20.2%. The annual mortality rates for years 2011, 2012, and 2013 may reflect the higher annual mortality rate associated with the establishment period.

Table 5: Survival rate, annual survival rate and annual mortality rate for all species by year.

Year	No. of Trees Assessed	Survival Rate (%)	Annual Survival Rate (%)	Annual Mortality Rate (%)
2007	174	57	92.4	7.6
2008	231	58	91.3	8.7
2009	233	67	92.3	7.7
2010	158	71	91.8	8.2
2011	84	56	82.4	17.6
2012	99	64	79.8	20.2
2013	66	82	81.8	18.2

DISCUSSION

Multiple urban forestry studies demonstrate variations in survival and annual mortality rates, depending upon the location of the study (Table 6). In general, our survival rates for 4 and 5 year time frames were lower than those found in other studies, but similar to the results of Nowak et al. (1990), who reported that areas of lower socio-economic status exhibited the highest tree mortality for the first two years after planting. In Tucson, the prolonged freeze of February 2011 was an unusual event (Orum et al. 2016). When we omit the less cold tolerant willow acacia from our mortality rate calculations, our results more closely resemble those documented in the literature. Without the willow acacia, 4 year survival rates would be 78% and the annual mortality rate 6.1%; 5 year, 76% and 5.2%; and 6 year, 63% and 7.3%. These values are in closer agreement with rates described in the literature (Table 6), except for the survey completed in Iowa, which had a survival rate of 91% (Thompson et al. 2004).

Stewardship and maintenance are the most critical factors influencing young tree survival (Roman 2013). Activities that increase tree survival include more frequent site visits, follow-up tree care, systematic monitoring, and planting species with high survival rates. Even though most of the trees were planted correctly for home shading, our discussions with families indicated a lack of knowledge of planting methods, watering needs, and general maintenance, which we attempted to remedy with our tree care classes. Proper watering techniques are especially important for the Chilean mesquite so that the tree does not develop a shallow root system.

Table 6: A comparison with other US studies in the peer-reviewed literature.

City	Survival Rate (%)	Annual Mortality Rate (%)	Time (Yrs)	Reference
Oakland and Berkeley, CA	66	19	2	Nowak et al. 1990
Milwaukee; Waukesha; and Stevens Point, WI	51.8 - 74.9	-	4	Miller and Miller 1991
21 cities in Iowa	91	6	3-4	Thompson et al. (2004)
New York City	3-6 years - 78.2 6-8 years - 73.0	-	3-8	Lu et al. (2010)
Philadelphia	50-100 depending upon species	Mean 4.5: MLE[1], 22 years MHL[2],15 years	2-10	Roman and Scatena (2011)
Meta-analysis, 16 programs across U.S.	-	3.5 to 5.1: MHL, 13 -20 years)	Varied	Roman and Scatena (2011)
Los Angeles	77.1	4.6	5	McPherson (2014)
Sacramento	70.9	6.6	5	Roman (2013)

[1]Mean life expectance (MLE)
[2]Mean half life (MHL)

This study demonstrates the need for bilingual outreach. In many low-income neighborhoods that are most in need of urban reforestation, traditional English language education and outreach programs may be less effective because many residents are not fluent in English. Through collaborations with non-profit organizations such as SERI, cities can create effective education and outreach campaigns that have the potential to improve tree survival. Another obstacle to a successful tree planting program on private property is the high cost of tree maintenance activities such as proper pruning, which may be unaffordable for many families. Providing funding opportunities through community grants or other mechanisms for tree maintenance is another way that cities can improve tree survival on private property and increase the overall urban tree canopy. An increased emphasis on tree stewardship will be crucial to the continued success of the SERI/TFT program.

The SERI/TFT project demonstrates that selecting tree species that can withstand local climate extremes is crucial to the success of a tree planting program. With its drought tolerance, showy bright yellow puff ball flowers, and unmistakable fragrance, the sweet acacia has long been a popular tree in Tucson (Peters 2018). Although its rated cold tolerance is similar to the blue palo verde and Chilean mesquite, more sweet acacia trees died in 2011 during the first severe freeze event in 30 years. Freeze events are an integral part of the Sonora Desert climatology, and the selection of cold tolerant tree species is crucial to the long-term success of any tree planting initiative in Tucson. In 2014, TFT eliminated sweet acacia and willow acacia from its list of recommended trees because of their intolerance to severe frost events. SERI is now distributing *Acacia smallii*, a more cold-tolerant species of sweet acacia than *Acacia farnesiana*.

Climate change caused by the combustion of greenhouse gases is already causing widespread tree deaths and fires in the American Southwest (Melillo, Richmond, and Yohe 2014). Rising temperatures will cause Tucson to become more arid even if precipitation does not decrease (Cook et al. 2015; Weiss et al. 2009). In the light of a changing climate, urban foresters need to revisit long standing recommendations of which tree species are appropriate for planting in their city. When selecting trees, the extremes of temperature and precipitation as well as average conditions must be considered (Gill et al. 2007), because climate change may cause storms to become more infrequent but more intense (USGCRP 2017).

While it is important to focus on low-income neighborhoods that traditionally have less green space, urban foresters also need to consider the age, structure and biodiversity of the entire urban forest. The loss of biodiversity in natural forest stands has increased the importance of preserving biodiversity in the urban forest (Alvey 2006). If large trees are dominant among the major species of street trees, the overall urban tree population may destabilize if many of the larger trees die in a relatively short period of time (Richards 1983). Climate change may also lead to increased insect outbreaks (Melillo, Richmond, and Yohe 2014), and relying on only a few tree species may make a city more susceptible to large-scale tree loss (Alvey 2006). For example, the emerald ash borer (*Agrilus planipenni*s Fairmaire) has now killed about 15 million trees in the mid-western United States (Alvey 2006), leaving many communities devoid of large street trees. In the mid-twentieth century, the aesthetics of many North American and European cities were adversely affected when millions of trees in North America and Europe were killed by Dutch elm disease (Strobel and Lanier 1981).

Because trees provide much needed cooling shade, trees have become a best management practice for mitigating increased temperatures caused by greenhouse gas combustion and the urban heat island effect (McPherson et al. 2005). However families of lower socioeconomic status are less likely to enjoy diverse plant and bird communities in their neighborhoods (Kinzig et al. 2005) for a variety of reasons. To begin correcting this environmental justice issue, SERI has created a rainwater harvesting program for low-income families in Tucson. Rainwater harvesting systems capture the rainwater runoff from roofs and yards, and make this water available for landscape use. Although Tucson Water offers homeowners rebates for the construction of a rainwater harvest system, the cost is often prohibitive for low-income families.

To fund this project, in 2015 SERI was awarded grants from Tucson Water and the United States Environmental Protection Agency. Twenty-six families that received a tree from the SERI/TFT project participated in a rainwater harvesting system pilot project, which will be described in a future paper. SERI's rainwater harvesting program will provide water to develop a healthy urban forest in Tucson while reducing the use of scarce tap water resources (Melillo, Richmond, and Yohe 2014).

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