Las Cruces, New Mexico Project Area

Community Forest Assessment

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This report is adapted from the standard i-Tree Ecosystem Analysis report that is generated upon submission of i-Tree Eco data. i-Tree Eco (formerly Urban Forest Effects model) was cooperatively developed by USDA Forest Service Northeastern Research Station (NRS), the USDA State and Private Forestry's Urban and Community Forestry Program and Northeastern Area, the Davey Tree Expert Company, and SUNY College of Environmental Science and Forestry.

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Tables and Figures

Definitions for **bold** words are available in the Glossary.
Monetary values are reported in US dollars throughout the report.

Executive Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. Different tree species contribute different benefits at varying levels, so a community that wants to manage the urban forest with specific benefits in mind may carefully select species to plant. Tree age and stature also greatly impact benefits, and this report provides an overview of the current relative age distribution and urban forest structure. Finally, managers can use this data to understand pests and diseases present, and not yet found in the area.

In 2013, the New Mexico Energy, Minerals and Natural Resources Department (EMNRD) contracted with Davey Resource Group (DRG) to collect field data and perform an analysis of the ecosystem services and benefits of trees on a landscape level. Data was collected in 201 designated plots which were randomly distributed across the Las Cruces project area and analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

Based on this sample, it is estimated that 257,000 trees exist across the sample area which covers 44 square miles. Tree canopy is estimated to cover 3.7% of the land area. The most common species found were desert willow, Italian cypress, and Afghan pine.

The tree population provides valuable benefits to the communities in the Las Cruces Project Area. The trees are important for air **pollution removal**, intercepting a net 92 **tons** of air pollution annually, valued at $235,000 dollars. They store 17,800 tons of carbon valued at $1.26 million and sequester 1,580 tons each year, valued at $112,000 dollars. **Carbon storage** and **carbon sequestration** values are based on a current market value of $71.21 per ton. Avoided carbon emissions are valued at $75,000 annually. The tree population reduces stormwater runoff by 898,000 cubic feet per year, valued at $59,800. Approximately 3,290 tons of oxygen are produced annually by this resource. The largest monetary value related to the urban forest is the structural value of the trees which is based on the replacement value of each tree at its present size and condition. This equates to $205 million.

Based on the i-Tree Eco model, the pests most likely to influence the urban forest in the project area are Southern pine beetle, sirex wood wasp, and pine shoot beetle. Predicting emergent pest infestations is more accurately done by local area experts, but the i-Tree Eco model provides valuable data about what pests may become a concern. These should be considered in conjunction with the opinions of local pest and disease experts.

Las Cruces Project Area urban forest managers can use this data to further understand the composition, species and age distribution, benefits and values, and possible risks in the urban forest. Air Quality and Utility managers can use the data to support planting and maintaining appropriate tree species to maximize air quality, stormwater runoff, and energy benefits. This data, unique to the project area, can help managers understand the unique attributes of their communities' urban forests.

Introduction

The urban forest contributes to a healthier, more livable, and prosperous Las Cruces. This Community Forest Assessment can provide benchmarks for the current amount of canopy, leaf surface area, and structure of the urban forest including both public and private trees. It also provides an overview of the ecosystem services of these trees, providing an important perspective for the city's understanding of the urban forest.

The urban forest contributes to a healthier, more livable, and prosperous Las Cruces.

The City of Las Cruces is the county seat of Doña Ana County, located in southern New Mexico. The climate is a hot desert at 3,908 feet elevation. The average rainfall is just 9.75 inches (NOAA). In this kind of environment, urban trees must be adapted to the weather conditions, or receive regular irrigation. The climate significantly limits the species palette in the region. Without irrigation, trees rarely survive, and even with irrigation, plant growth rates are typically slow, and small-stature trees are common.

The project area included communities within the city limits of Las Cruces, New Mexico. In order to provide a more accurate representation of the trees in the urban forest, the project area did not include undeveloped portions of the city, or the airport. As a result, the total included acreage was 28,174, or 44 square miles out of the city's 76.3 square miles of land.

Methods

Project Area

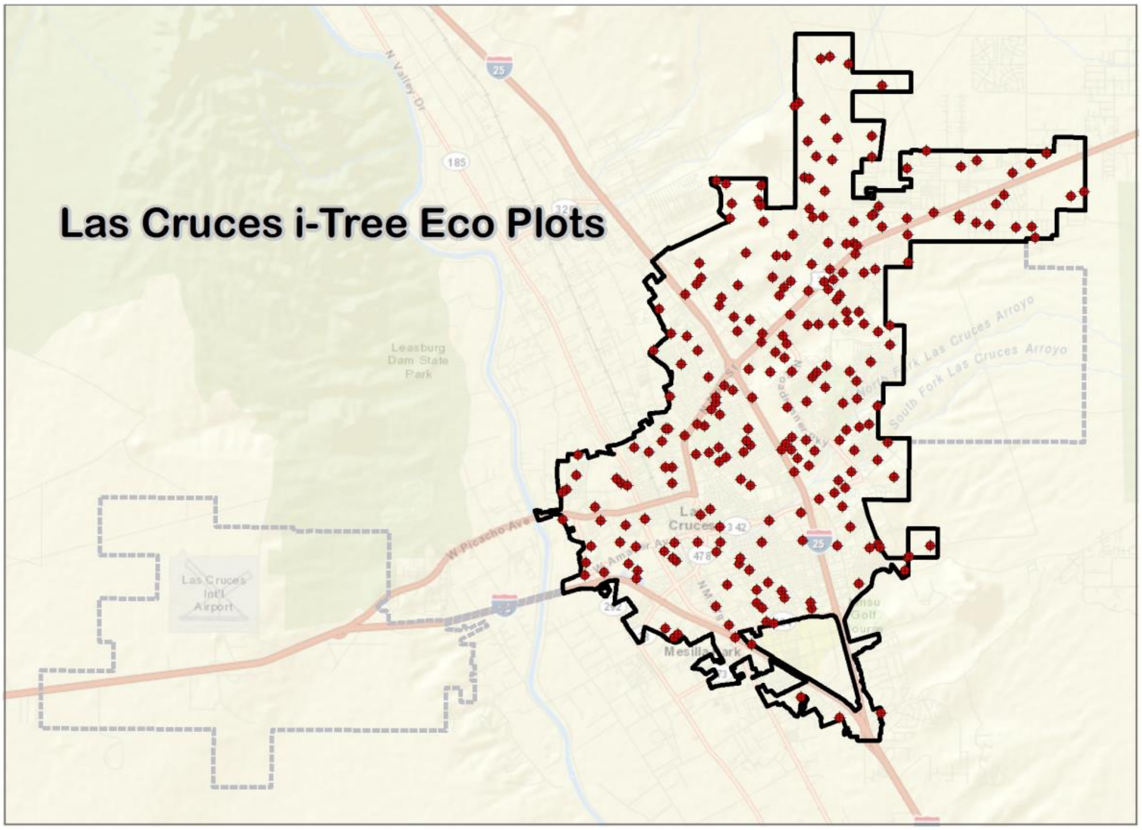

Figure 1. Project Area Boundaries, Plot Locations, and City Limits

The study area includes the 44 square miles within the black boundary in Figure 1. The red dots show the random distribution of the 201 measured plots. This area was selected because these are primarily urban areas of the city, and likely more consistent with the i-Tree Eco model. It is expected that the vegetation in the included areas most profoundly influences the urban ecosystem, providing the benefits calculated by the i-Tree Eco model. That is not to say that the trees and shrubs in the excluded areas are not important in providing air quality, stormwater, carbon, and energy benefits, but their influence in the i-Tree Eco model is diminished since they are not in close proximity to urban infrastructure and air conditioned buildings, so their contribution is not likely consistent with the more urban land areas.

The excluded areas provide benefits to the community and if they become more developed should be included in future studies. One factor that is not calculated in the study is the urban heat island effect. Vegetation on land outside the study area may mitigate heat associated with buildings and paved surfaces within the study area, and those benefits are not reflected in this model, which is geared toward understanding tree benefits in urbanized areas (Weng et al., 2003).

For example, a tree in an undeveloped area may provide the same carbon storage benefits as its urban counterpart, but because it is not in close proximity to infrastructure, the stormwater benefits are negligible. The pollutant absorption capacity depends on many factors including levels of pollutants, wind and dispersal, and proximity to the source of pollution; thus the capacity of a tree in an undeveloped area to absorb pollution is difficult to calculate with this model which presumes urban infrastructure and activities are nearby. The tree is also unlikely to provide substantial property value benefits or have a replacement value since wildland trees that fail are not typically replaced. Finally, since the tree is not near buildings, it cannot mitigate the energy use of air-conditioned space. So, while it is fair to say the trees still have value and provide benefits, those benefits do not fit with the attributes in the i-Tree Eco model, and it is reasonable to exclude them from the study.

i-Tree Eco Model and Field Measurements

Model Components

The model selected to calculate urban forest benefits is the i-Tree Eco model. The i-Tree Eco model is designed to use standardized field data from randomly located plots and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects [Nowak & Crane, 2000], including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<2.5 microns and <10 microns).
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants.
- Structural value of the forest as a replacement cost.
- Potential impact of infestations by pests or pathogens

In the field, 201 0.1-acre plots were randomly distributed across the study site using the ArcView GIS random point generation tool. All field data was collected during the leaf-on season to properly assess tree canopies. Within each plot, typical data collection included land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings [Nowak et al., 2005 and Nowak et al., 2008].

The land uses were determined based on the primary use of the land at the sample site. Residential was assigned to sites where the primary use was housing. Commercial/Industrial was assigned to buildings and associated landscaped areas and parking lots where the primary use was the sale of goods or services, or manufacturing. Parks included publically-owned land where the primary activities were recreational, or the land was protected for conservation purposes. Mixed Use included combinations of the preceding land uses. Vacant included land with no clear intended use, while abandoned buildings and vacant structures were classified to their original intended use.

The i-Tree Eco model uses a local list of invasive plants to determine how many of the trees in the sample are invasive. In New Mexico, the list was created by compiling the lists from adjacent states since there was no existing list for New Mexico. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Urban Tree Benefit and Pathogen and Pest Risk Calculations

To calculate current carbon storage, biomass for each tree was calculated by incorporating measured tree data into equations from the literature. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations [Nowak, 1994]. To adjust for this difference, i-Tree Eco multiplies biomass results for open-grown urban trees by 0.8. The i-Tree Eco model converted tree dry-weight biomass to stored carbon by multiplying by 0.5.

To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1. Carbon storage and carbon sequestration values are based on i-Tree Eco estimated local carbon values.

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition [Nowak, Hoehn, & Crane, 2007].

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models [Baldocchi, 1988 and Baldocchi, Hicks, & Camara, 1987]. As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature [Bidwell &

Fraser, 1972 and Lovett, 1994] that were adjusted depending on leaf phenology and leaf area. Removal estimates of particulate matter less than 10 microns incorporated a 50% resuspension rate of particles back to the atmosphere [Zinke, 1967]. Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values [Hirabayashi, Kroll, & Nowak, 2011, Hirabayashi, Kroll, & Nowak, 2012, and Hirabayashi, 2011].

Air pollution removal value was calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter <2.5 microns (PM2.5) using the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP). The model uses a damage-function approach that is based on the local change in pollution concentration and population [Davidson et al., 2007].

National median externality costs were used to calculate the value of carbon monoxide removal and particulate matter less than 10 microns and greater than 2.5 microns [Murray, Marsh, &Bradford, 1994]. PM10 denotes particulate matter less than 10 microns and greater than 2.5 microns throughout the report. As PM2.5 is also estimated, the sum of PM10 and PM2.5 provides the total pollution removal and value for particulate matter less than 10 microns.

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series [USFS].

Seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature [McPherson & Simpson, 1999] using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information [Nowak et al., 2002].

Potential pest and pathogen risk is based on their range maps and the known pest and pathogen host species that are likely to experience mortality. Range maps from the Forest Health Technology Enterprise Team (FHTET) [2010] were used to determine the proximity of each pest or pathogen to Doña Ana County. It was established whether the insect/disease occurs within the county, is within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away.

Findings

Tree Population Characteristics

This section provides an overview of the species, condition, density, geographic origin, and age (size class) of the tree population. These values help provide context for the following sections on canopy cover and leaf area, as well as the ecological and economic benefits of Las Cruces' public and private trees.

Species Distribution

The sample identified 36 unique tree species, but the urban forest likely has far greater diversity. Table 1 and Figure 2 show the ten most prevalent species found in the sample. Based on this sample, it is estimated that the urban forest of Las Cruces has a total of 257,000 trees with a tree canopy cover of 3.7%. Because of the sampling method used, the species distribution has very high error rates, and species proportions should not be relied on for management decisions. The i-Tree Streets model is more appropriate for determining species composition in the community if desired.

Species	# of Trees	Standard Error (+/-)	Error %
Desert willow	46,237	41,119	89%
Italian cypress	40,621	24,265	60%
Afghan pine	30,358	17,047	56%
Chaste tree	15,990	9,285	58%
Honey mesquite	12,544	4,397	35%
Velvet ash	11,514	4,121	36%
Siberian elm	10,362	8,186	79%
Black locust	10,136	8,163	81%
Chitalpa	8,867	3,731	42%
Oriental arborvitae	7,155	5,856	82%

Table 1. Tree Species Composition

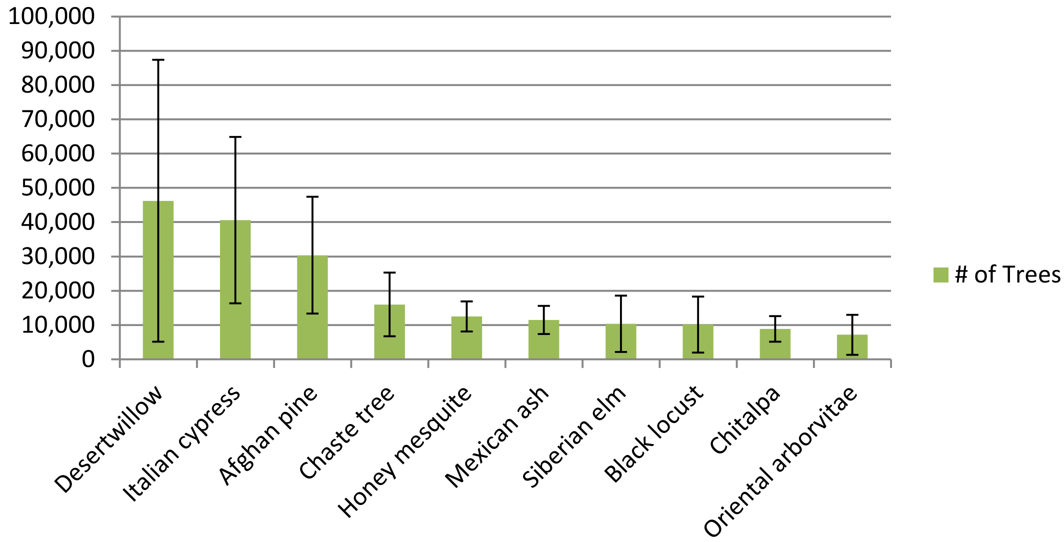

Figure 2. Common Species

Species Richness

Table 2 shows the number of species found in this sample in each Land Use type. This information is provided to show the diversity of trees in the sample, but is not likely a reflection of the full species diversity across the landscape due to the sample size of just 201 plots. The purpose of this plot-based sampling method is to provide a landscape view of the region's public and private trees. A complete tree inventory can provide a better understanding of species diversity in the project area, but would be prohibitively resource intensive.

The i-Tree Eco model uses established calculations for species diversity indexes, which allow quantitative comparisons of species richness. The Shannon-Wiener Diversity Index assumes that all the species in an area have been sampled, and has a moderate sensitivity to sample size. The Menhinick Index is an indicator of species dominance and has a low sensitivity to sample size and therefore may be more appropriate for comparisons among cities. The Simpson's Diversity Index is an indicator of species dominance and has a low sensitivity to sample size and is appropriate for comparisons between land-use types.

Table 2. Species Richness

Primary Index	Species	Species/ Hectare	Shannon-Wiener Diversity Index	Menhinick Index	Simpson's Diversity Index
Mixed Use	5	4.5	1.3	1.2	3.1
Residential	30	4.1	2.8	2.6	10.6
Commercial/Industrial	9	3.5	1.5	1.5	3
Other/Vacant	1	0.6		0.6	1
Park	6	0.8	1.4	1.1	3.9
Citywide	36	1.8	2.9	2.4	11.4

Trees by Land Use Distribution

Based on the sampled plots, about 257,000 trees are present in the study area on public and private property in Las Cruces. Trees in residential areas make up 61% of the trees in this assessment. This is based on stratifying the sampled plots to the land use areas of each type to determine an estimated number of trees by land use.

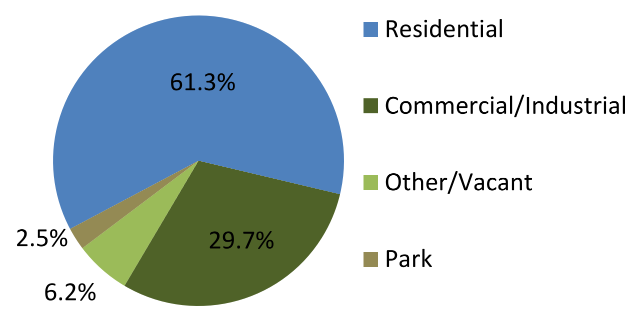

Figure 3. Percent of Trees by Land Use

Tree Density

Another way to consider tree distribution is to analyze the number of trees per acre in each land use type (Figure 4). Residential land uses typically feature the most trees per acre, and Las Cruces is no exception. The residential areas had 18.7 trees per acre, followed by mixed use with 16.4 trees per acre. Over all, the tree density in the studied area is 9.1 trees per acre. Appendix II shows comparable values from other cities, as reported by i-Tree Eco.

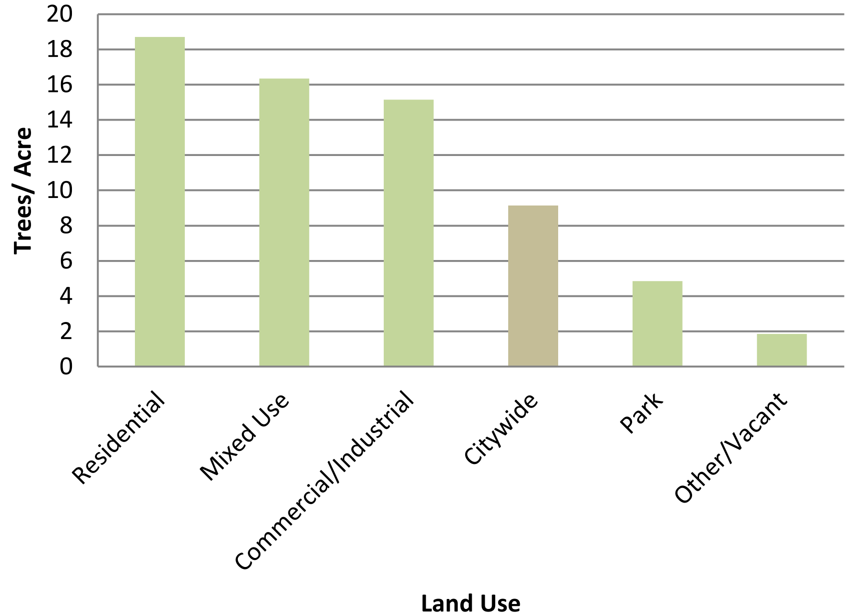

Figure 4. Trees per Acre by Land Use

Relative Age Distribution

For most woody plants, the DBH increases incrementally annually, so it may be used to estimate the age of the population. Based on the relative relationship between age and diameter, the distribution of the sampled trees indicates a young or small-statured population with 64% of trees under 6” DBH (Figure 5).

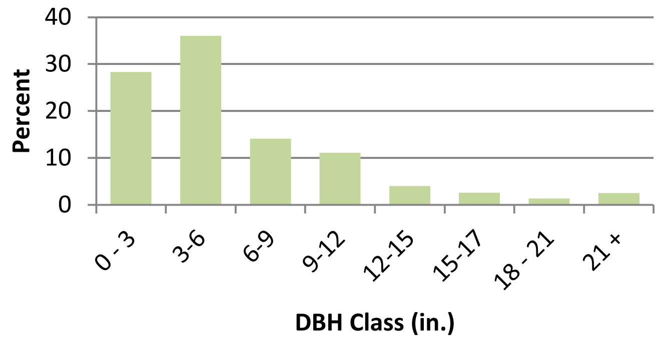

Figure 5. Citywide Relative Age Distribution

Considering the land uses, Figure 6 shows some patterns by land use, for example, the mixed use areas had the most trees in the 0-3” DBH range.

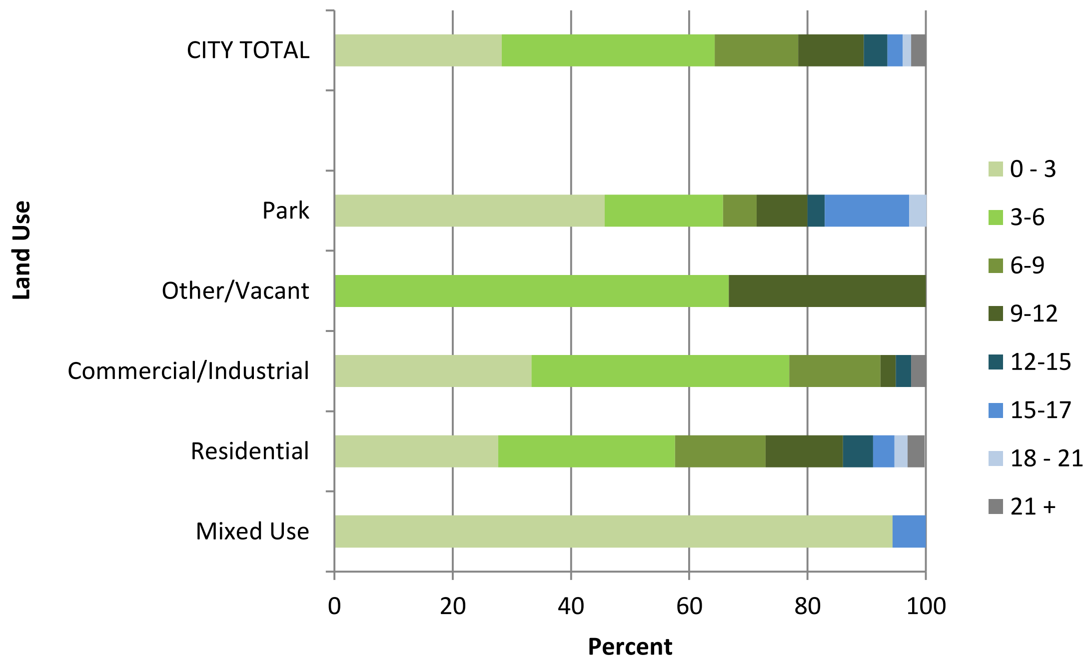

Figure 6. Age Distribution by Land Use

Tree Condition

Tree condition can be related to species fitness, tree age, environmental stressors, and maintenance, and these typically vary with land use. The majority (76%) of trees in the sample are in good to excellent condition. The parks had the highest percent of dead dying and critical trees while the trees in the residential and mixed use areas were in the best condition (Figure 7 and Table 3).

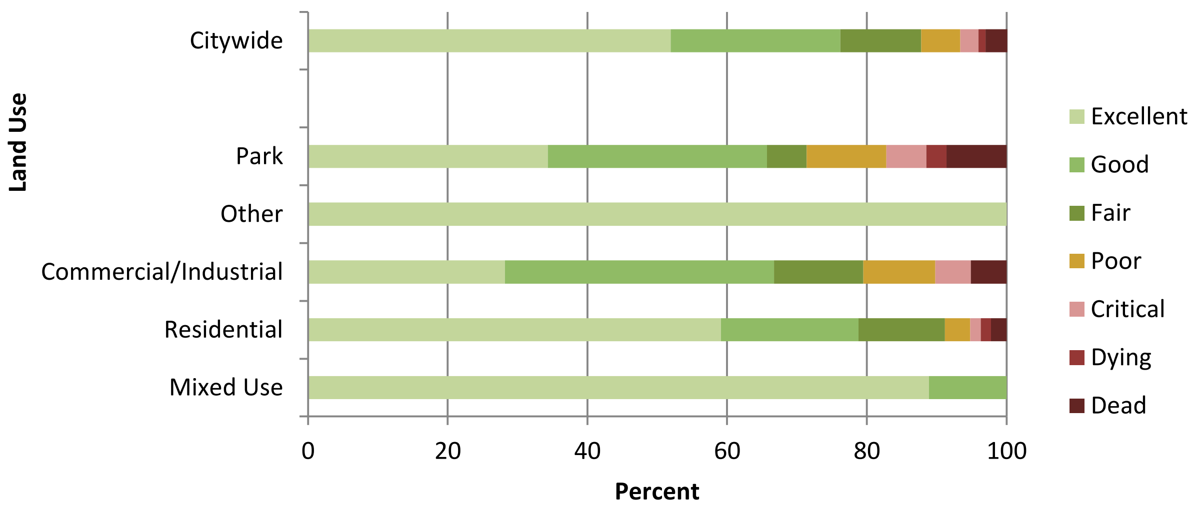

Figure 7. Condition (%) by Land Use

Table 3. Condition (%) by Land Use

Land Use	Excellent		Good		Fair		Poor		Critical		Dying		Dead	
	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)
Mixed Use	88.9	10	11.1	10										
Residential	59.1	8.42	19.7	5.18	12.4	3.46	3.6	1.74	1.5	1.01	1.5	1.03	2.2	1.24
Commercial/ Industrial	28.2	12.4	38.5	14.5	12.8	4.14	10.3	5.48	5.1	4.11			5.1	2.66
Other/Vacant	100	0												
Park	34.3	14.5	31.4	12.2	5.7	3.98	11.4	5.52	5.7	4.1	2.9	2.92	8.6	8.27
Citywide	51.9	6.36	24.3	5.35	11.6	2.45	5.6	1.95	2.6	1.37	1	0.64	3.1	1.11

Tree Species Origin Distribution

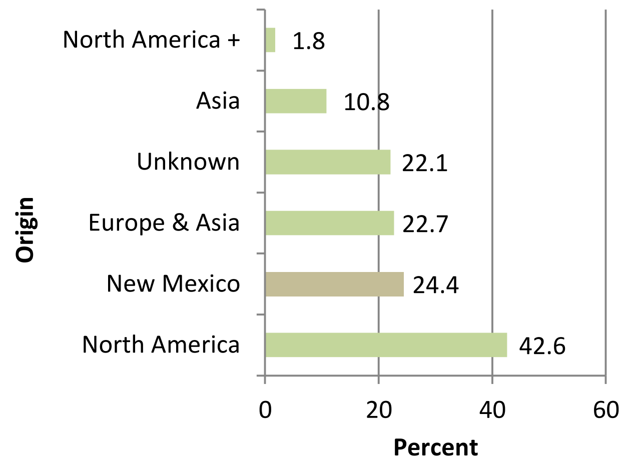

Figure 8. Percent of Live Trees by Species Origin

Urban forests are composed of a mixture of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction of the urban forest resource by a species-specific pest or pathogen, but it can also pose a risk to native plants if some of the exotic species spread beyond planting sites and aggressively suppress the establishment of native species in both the urban and wildland areas. Those invasive plant species, are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas [USDA, 2011].

Figure 8 shows the origin distribution of species found in the sample. In Las Cruces, about 43% of the trees are species native to North America, and 24% are native to New Mexico. Totals do not sum to 100% due to rounding, and because New Mexico natives are a subset of North American natives.

Five of the 36 tree species sampled in Las Cruces are identified as invasive based on invasive species lists of nearby states. However, local managers suggest the three species below are the most likely to actually be invasive in the Las Cruces area (Table 4). These invasive species comprise 6% of the tree population, and 21% of the leaf area. The model does not calculate the level of impact these trees have on local ecosystems, an assessment best left to the determination of local forest managers.

Table 4. Trees Categorized as Invasive in New Mexico

Species	Number of trees	% of Population	Leaf Area (mi2)	% of Leaf Area
Siberian elm	10,362	4.03	0.44	8.16
White mulberry	4,293	1.67	0.62	11.36
Tree of heaven	1,151	0.45	0	0.08
Total	15,806	6.15	1.18	21.71

Cover and Leaf Area

Importance Value and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. In the project area, the most impactful species in terms of leaf area and population are Afghan pine, desert willow, and Italian cypress, composing 46% of the population and 40% of the leaf surface area. The 20 most important species are listed in Table 5. Importance values (IV) are calculated as the sum of relative leaf area and relative composition.

Table 5. Top 20 Species by Importance Value

Species	Percent Population	Percent Leaf Area	Importance Value
Afghan pine	11.8	26.3	38.1
Desertwillow	18.0	11.7	29.7
Italian cypress	15.8	1.5	17.3
Velvet ash	4.5	12.8	17.2
White mulberry	1.7	11.4	13.0
Siberian elm	4.0	8.2	12.2
Black locust	3.9	4.6	8.6
Honey mesquite	4.9	3.5	8.4
Chaste tree	6.2	2.1	8.3
Chitalpa	3.4	3.9	7.3
Oriental arborvitae	2.8	1.3	4.1
Live oak	1.8	2.1	3.9
Purpleleaf plum	2.2	1.0	3.2
London plane	0.8	2.3	3.1
Pinyon pine	1.8	0.6	2.4
Willow spp	0.4	1.8	2.2
Neomexican elderberry	1.8	0.4	2.2
Ocotillo	1.3	0.7	2.1
Texas red oak	1.5	0.5	2.0
Mexican fan palm	1.7	0.2	1.9
Other species	9.6	3.3	12.9

Groundcover and Canopy

Groundcover types impact stormwater runoff, availability of planting sites, and indicate the degree of urban density. The most dominant land cover type citywide was bare soil, comprising 54% of the sample area. Shrubs and trees were calculated as a separate layer above the ground cover. Shrub cover was estimated at 7% (Table 6). Tree canopy is estimated at 3.7% of the city area.

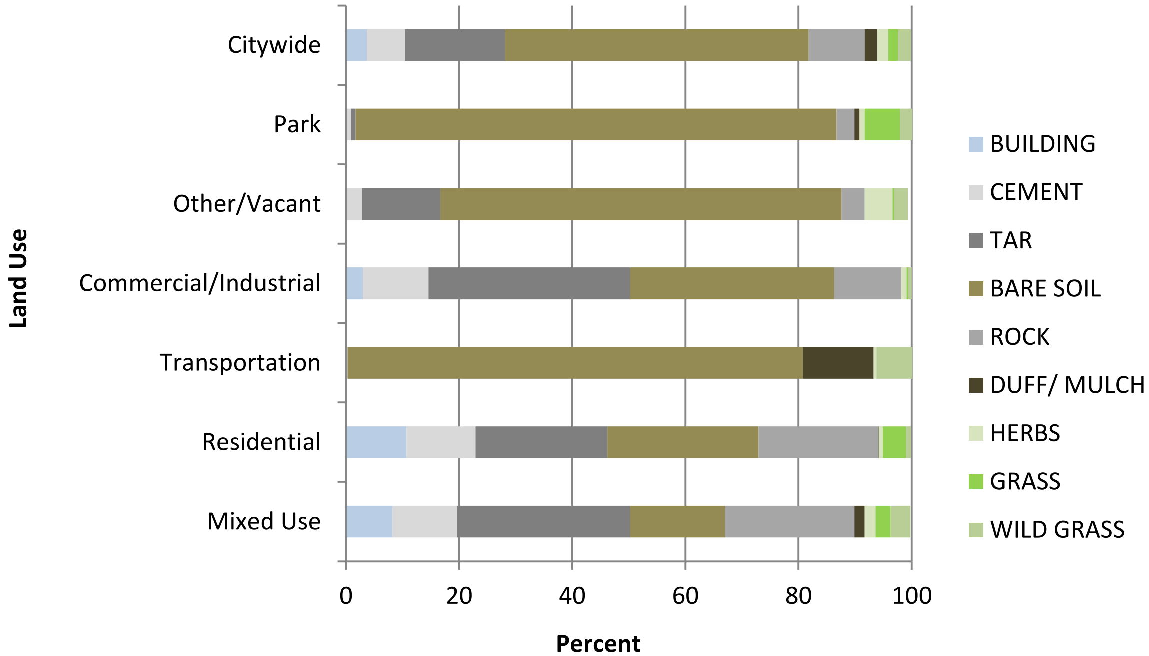

Figure 9. Ground Cover Type Distribution

Table 6. Percent Ground Cover by Land Use

Ground Cover	BUILDING		CEMENT		TAR		BARE SOIL		ROCK		DUFF/ MULCH	
Land Use	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)
Mixed Use	8.2	3.05	11.5	4.08	30.5	10.3	16.8	6.53	22.9	8.42	1.8	1.71
Residential	10.7	1.71	12.2	1.23	23.3	2.76	26.7	3.99	21.2	2.26	0.1	0.08
Transportation			0.3	0.22			80.5	10.2			12.5	10.8
Commercial/Industrial	3	1.31	11.6	2.95	35.6	7.12	36.1	7.9	11.9	3.25		
Other/Vacant			2.8	1.14	13.9	5.92	70.9	6.8	4.1	3.74		
Park	0.1	0.07	0.8	0.35	0.8	0.48	85	3.52	3.2	1.63	0.9	0.94
Citywide	3.7	0.56	6.7	0.73	17.7	2.35	53.7	3.27	9.9	1.45	2.2	1.84

Ground Cover	HERBS		GRASS		WILD GRASS		WATER		SHRUB	
Land Use	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)
Mixed Use	1.9	1.42	2.7	1.83	3.5	3.23	0.1	0.09	2.1	0.7
Residential	0.7	0.16	4.1	1.22	0.9	0.35			4.8	1.13
Transportation	0.5	0.25			6.3	5.41			8.3	7.14
Commercial/Industrial	0.9	0.39	0.2	0.19	0.7	0.28			5.3	1.96
Other/Vacant	4.9	2.41	0.3	0.3	2.4	1.03	0.6	0.61	7.4	3.47
Park	0.9	0.23	6.2	2.45	2.2	0.71			15.9	1.61
CITY TOTAL	2	0.74	1.7	0.39	2.3	0.98	0.2	0.18	6.8	1.68

Economic and Ecological Benefits

Structural and Functional Values

Urban forests have structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree) andfunctional values (either positive or negative) based on the functions the trees perform (e.g., removing pollution, reducing energy use).

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees [Nowak, Crane, & Dwyer, 2002]. Annual functional values also tend to increase with increased number and size of healthy trees, and are usually on the order of several million dollars per year. Through proper management, urban forest values can be increased; however, the values and benefits can decrease if the amount of healthy tree cover declines.

Structural values:

- Structural value: $205 million
- Carbon storage: $1.26 million

Annual functional values:

- Carbon sequestration: $112,000
- Pollution removal: $235,000
- Lower energy costs and carbon emission reductions: $638,000
- Avoided Stormwater Runoff: $59,800

Relative Tree Effects

The urban forest in Las Cruces provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average **municipal carbon emissions** [EIA, 2003, and Census.gov, 2003], average **passenger automobile emissions** [EPA, 2002, BTS 2004, and Graham, Wright & Turhollow, 1992], and average **household emissions** [EIA, 2001].

In Las Cruces, carbon storage is equivalent to:

- Amount of **carbon emissions** in 11 days
- Annual carbon emissions from 10,700 automobiles
- Annual carbon emissions from 5,350 single-family houses

Carbon monoxide removal is equivalent to:

- Annual **carbon monoxide emissions** from 6 automobiles
- Annual carbon monoxide emissions from 24 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual **nitrogen dioxide emissions** from 356 automobiles
- Annual nitrogen dioxide emissions from 237 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual **sulfur dioxide emissions** from 616 automobiles
- Annual sulfur dioxide emissions from 10 single-family houses

Particulate matter less than 10 micron (PM10) removal is equivalent to:

- Annual **PM10 emissions** from 105,000 automobiles
- Annual PM10 emissions from 10,100 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Las Cruces, NM in 0.9 days
- Annual carbon emissions from 900 automobiles
- Annual carbon emissions from 500 single-family houses

For definitions and calculations, see Appendix I.

Air Quality

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to trees and shrubs and ecosystem processes, and reduced visibility. Doña Ana County often does not meet the National Ambient Air Quality Standards for particulate and ozone. As a result, the county must actively search for programs to reduce these pollutants. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from power plants. Trees also emit volatile organic compounds that can contribute to ozone formation. Recently, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation [Nowak & Dwyer, 2007].

Pollution removal by trees and shrubs in Las Cruces was estimated using field data, hourly air quality data and weather data. It is estimated that trees and shrubs remove a total of 92 tons of air pollution with an associated value of $235,000 dollars. Figure 10 shows the tons of pollutants removed and their associated values. Pollution removal was greatest for ozone at 45 tons while the value of PM10 removed is greatest at $185,961. This estimate is based on estimated local incidence of adverse health effects of the BenMAP model and national median externality costs associated with pollutants [Abdollahi, Ning, & Appeaning, 2000].

The i-Tree Eco model produced an uncommon result for PM2.5, with a negative annual PM2.5 removal value in contrast to the positive yearly amount of PM2.5 removed. The i-Tree Eco model calculates pollution removal values based on changes in pollution concentration, not overall tons of pollution removed. Trees remove PM2.5 when particulate matter is deposited on leaf surfaces, and rain dissolves and transfers the PM2.5 to the soil. However, under certain meteorological conditions (e.g., a month with no rain), trees can re-suspend more particles than they remove, thus causing a negative pollution concentration change.

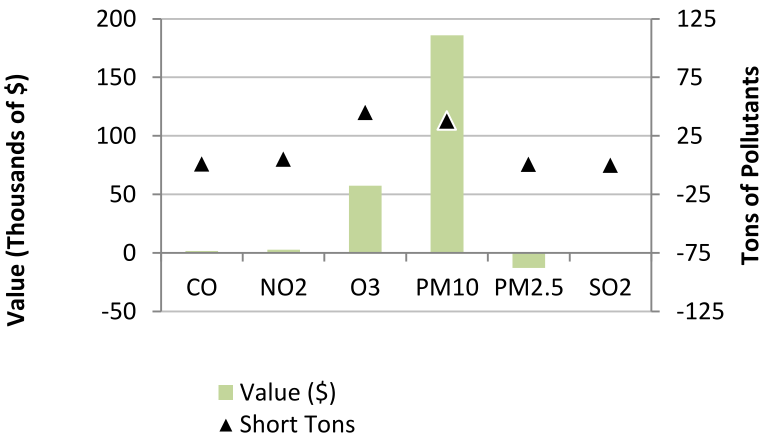

Figure 10. Annual Pollution Removal (Bars) and Associated Value (Points)

Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue, altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power plants [Nowak & Dwyer, 2007].

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The annual sequestration of the project area trees is about 1,580 tons of carbon per year with an associated value of $112,000. The populations of Afghan pine and Mexican ash sequester the greatest amounts of carbon over their lifetime, while smaller stature trees such as chaste trees have less sequestration capacity. Figure 11 shows the species that sequester the largest amounts of carbon each year.

As trees grow, they store more carbon as wood. As trees die and decay, they release much of the stored carbon back to the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be lost if trees are allowed to die and decompose. Trees in the project area are estimated to store 17,800 tons of carbon, valued at $1.26 million. **Carbon storage** and **carbon sequestration** values are calculated based on $71.21 per ton (see Appendix I for more details).

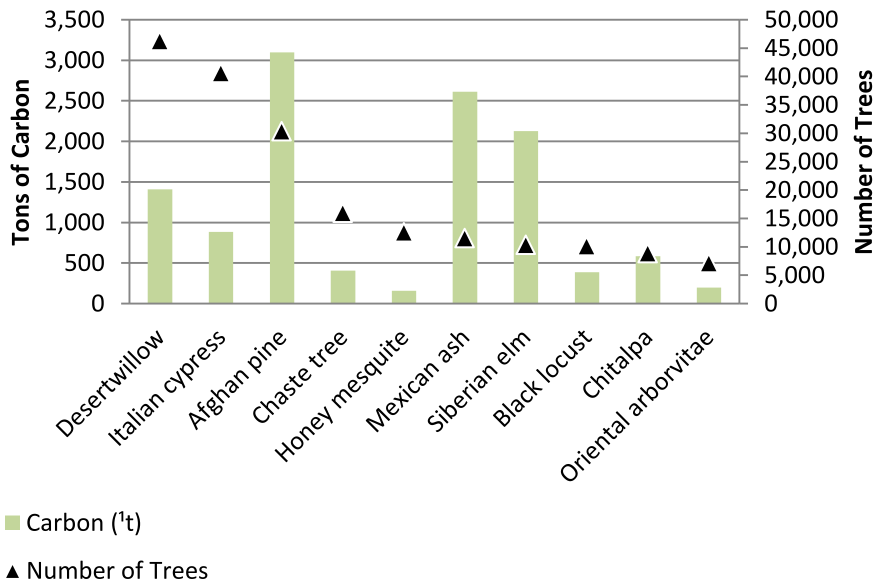

Figure 11. Top 10 Carbon Sequestering Species

Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The net annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in the project area are estimated to produce 3,290 tons of oxygen per year. Table 7 shows the varying oxygen production of different tree species. This tree benefit is monetarily insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen [Broecker, 1970]. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent, so the monetary value of this contribution is considered negligible.

Table 7. Top 20 Oxygen Producing Species

Species	Oxygen (tons)	Net Carbon Sequestration (tons/yr)	Number of trees	Leaf Area (square miles)
Desert willow	672.44	252.16	46,237.00	0.64
Afghan pine	435.37	163.26	30,358.00	1.43
Mexican ash	421.52	158.07	11,514.00	0.69
White mulberry	354.06	132.77	4,293.00	0.62
Italian cypress	290.95	109.11	40,621.00	0.08
Chitalpa	214.23	80.34	8,867.00	0.21
Black locust	159.85	59.94	10,136.00	0.25
Chaste tree	140.18	52.57	15,990.00	0.11
Live oak	127.93	47.97	4,606.00	0.11
Honey mesquite	111.61	41.85	12,544.00	0.19
Oriental arborvitae	74.78	28.04	7,155.00	0.07
Willow spp	65.43	24.54	1,151.00	0.10
Purpleleaf plum	61.94	23.23	5,757.00	0.05
Ocotillo	59.17	22.19	3,454.00	0.04
Cottonwood spp	53.82	20.18	1,151.00	0.05
Texas red oak	53.38	20.02	3,917.00	0.03
London plane	49.68	18.63	1,958.00	0.13
Neomexican elderberry	38.98	14.62	4,606.00	0.02
Yaupon	27.28	10.23	2,303.00	0.02
Pinyon pine	24.43	9.16	4,606.00	0.03

Avoided Stormwater Runoff

Surface runoff can be a cause for concern in urban areas, as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of precipitation is intercepted by vegetation (trees, grasses, forbs, and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff. In urban areas, the large extent of impervious surfaces increases the amount of surface runoff, and the cost of infrastructure a community must invest in managing stormwater for the safety of residents and property.

One limitation of the i-Tree Eco model is that grasses and forbs are not specifically accounted for in reporting benefits. In areas such as the desert southwest, these land cover types play a very important role in managing stormwater runoff. Grasses and forbs in the desert southwest may have a proportionately greater role than in other climate types where trees and shrubs are more plentiful. While no specific benefit data is available based on the model, the overall percentage of these land cover types found in this study is substantial (Table 8). Thus realized stormwater benefits are likely even higher if herbs, grasses, and forbs are considered.

Table 8. Vegetation NOT Accounted for in Model

Ground Cover	HERBS		GRASS		WILD GRASS	
Land Use	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)
Mixed Use	1.9	1.42	2.7	1.83	3.5	3.23
Residential	0.7	0.16	4.1	1.22	0.9	0.35
Transportation	0.5	0.25			6.3	5.41
Commercial/Industrial	0.9	0.39	0.2	0.19	0.7	0.28
Other/Vacant	4.9	2.41	0.3	0.3	2.4	1.03
Park	0.9	0.23	6.2	2.45	2.2	0.71
CITY TOTAL	2.0	0.74	1.7	0.39	2.3	0.98

Urban trees are beneficial in reducing surface runoff. Trees intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees throughout the project area help to reduce runoff by an estimated 898,000 cubic feet a year with an associated value of $59,800million dollars. Figure 12 shows the tree species that provide the highest rainfall interception values. This figure demonstrates that population numbers alone do not dictate the interception value, rather, interception is related to leaf surface area which is influenced on tree age, health, species, and stature.

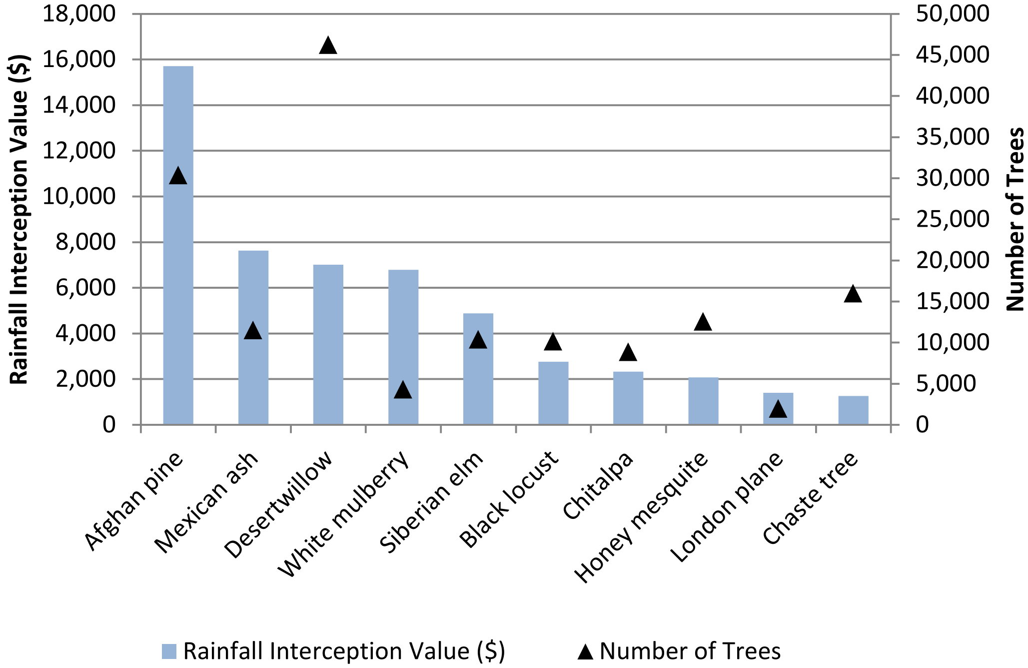

Figure 12. Rainfall Interception Value (bars) and Number of Trees (points)

Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. The values for Table 9 were calculated considering savings during heating and cooling seasons. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to air conditioned residential buildings [McPherson & Simpson, 1999].

Trees in the project area are estimated to reduce energy-related costs from residential buildings by $563,000 annually (Table 9). Trees also provide an additional $75,046 in value by reducing the amount of carbon released by fossil-fuel based power plants, a reduction of 1,050 tons of carbon emissions (Table 9 and 10). Negative numbers indicate an increased energy use or carbon emission.

Table 9. Annual Energy Savings Due to Trees Near Residential Buildings

	Heating	Cooling	Total
MBTU[1]	-5,435	n/a	-5,435
MWH[2]	-141	5,884	5,743
Carbon avoided (t[3])	-110	1,164	1,054

[1]One million British Thermal Units
[2]Megawatt-hour
[3]Short ton

Table 10. Annual Savings[1] ($) in Residential Energy Expenditure

	Heating	Cooling	Total
MBTU[2]	-57,772	n/a	-57,772
MWH[3]	-15,242	636,060	620,818
Carbon avoided	-7,850	82,896	75,046

[1]Based on the prices of $108.1 per MWH and $10.63 per MBTU
[2]One million British Thermal Units
[3]Megawatt-hour

Potential Urban Forest Health Impacts

Pathogen and Pest Proximity and Risk

Pathogens and pests can infect and infest urban forests, potentially killing trees and reducing the health, value and sustainability of the urban forest. As pathogens and pests have differing tree hosts, the potential damage or risk of each pest will differ among cities. Thirty-one pathogens and pests were analyzed for their potential impact and compared with range maps [ForestHealth.info, 2010] for the contiguous United States. In Figure 13, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest was outside of these ranges in 2013.

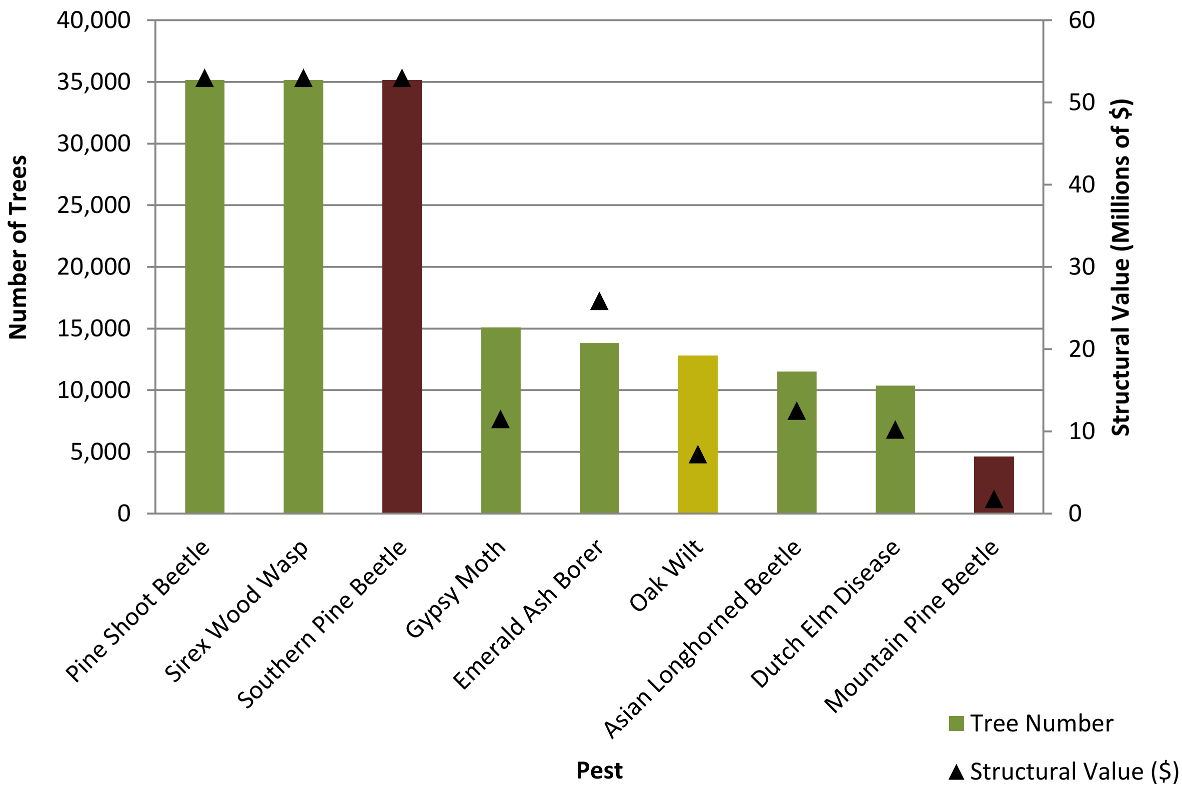

Figure 13. Number of Susceptible Trees (Bars) and Structural Value (Points) by Pest

The pathogens with the largest potential impact on tree populations in the project area are described below. The three most widely impactful pests, should they ever migrate to the area, are pine shoot beetle, sirex wood wasp, and southern pine beetle. It should be noted that i-Tree Eco uses the inventory data to calculate the damage potential of a given pathogen to the area of interest. The model does not calculate whether there is a reasonable risk that this pathogen will move there in the foreseeable future. The model calculates the damage potential, assuming the pathogen will reach the study area and attack the associated tree species.

The following are some of the pests and pathogens identified by the model:

Asian Longhorned Beetle (ALB) [NASPF, 2005] is an insect that bores into and kills a wide range of hardwood species. ALB poses a threat to 4.5% of the Las Cruces, NM urban forest, which represents a potential loss of $12.5 million in structural value.

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch Elm Disease (DED) [NASPF, 1998]. Since first reported in the 1930s, it has killed over 50% of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Las Cruces, NM could possibly lose 4.0% of its trees to this pest ($10.2 million in structural value).

Emerald Ash Borer (EAB) [NASPF, 2005] has killed thousands of ash trees in parts of the United States. EAB has the potential to affect 5.4% of the population ($25.9 million in structural value).

The Gypsy Moth (GM) [NASPF, 2005] is a defoliator that feeds on many species causing widespread defoliation and tree death if outbreak conditions last several years. This pest threatens 5.9% of the population, which represents a potential loss of $11.5 million in structural value.

Mountain Pine Beetle (Gibson, 2009) [27] is a bark beetle that primarily attacks pine species in the western United States. MPB has the potential to affect 1.8% of the population ($1.77 million in structural value).

Oak Wilt (OW) [Rexrode, 1983], which is caused by a fungus, is a prominent disease among oak trees. OW poses a threat to 5.0% of the Las Cruces, NM urban forest, which represents a potential loss of $7.22 million in structural value.

The Pine Shoot Beetle (PSB) [Ciesla, 2001] is a wood borer that attacks various pine species, though Scotch pine is the preferred host in North America, but local experts do not think its occurrence in Las Cruces is likely.

Although the Southern Pine Beetle (SPB) [Clarke, 2009] will attack most pine species, its preferred hosts are loblolly, Virginia, pond, spruce, shortleaf, and sand pines. This pest threatens 13.7% of the population, which represents a potential loss of $53.0 million in structural value. The Sirex Wood Wasp (SW) [Haugen, 2005] is a wood borer that primarily attacks pine species. SW poses a threat to

13.7% of the Las Cruces, NM urban forest, which represents a potential loss of $53.0 million in structural value.

In addition to the modeled pests, Chalcid Wasp (Family: Eurytomidae) was found in 2008 on Afghan Pine. The pest could impact 11.8% of the population. Local experts also believe mountain pine beetle (*Dendroctonus ponderosae*) may become a problem in the future.

Appendix I. Glossary and Calculations

Carbon dioxide emissions from automobile assumed six pounds of carbon per gallon of gasoline if energy costs of refinement and transportation are included (Graham, Wright, & Turhollow, 1992)

Carbon emissions Total city carbon emissions were based on 2003 US per capita carbon emissions – calculated as total US emissions (EIA, 2003) divided by the 2003 US total population (Census.gov). This value was multiplied by the population of Las Cruces (555,417) to estimate total city carbon emissions.

Carbon storage The amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. Carbon storage and carbon sequestration values are calculated based on $71.21 per ton.

Carbon sequestration The removal of carbon dioxide from the air by plants. Carbon storage and carbon sequestration values are calculated based on $71.21 per ton.

Diameter at Breast Height (DBH) Is the diameter of the tree measured 4’6” above grade.

Energy saving Value is calculated based on the prices of $108.1 per MWH and $10.63 per MBTU.

Household emissions (average) based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household (EIA, 2001)

CO2, SO2, and NOx power plant emission per KWh (EPA)

CO emission per kWh assumes 1/3 of one% of C emissions is CO (EIA, 1994)

PM10 emission per kWh (Layton, 2004, 2005)

CO2, NOx, SO2, PM10, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) (Abraxas Energy Consulting)

CO2 and fine particle emissions per Btu of wood (Houck et al., 1998)

CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) (www.env.bc.ca, 2005)

Emissions per dry ton of wood converted to emissions per Btu based on average dry weight per cord of wood and average Btu per cord (ianrpubs.unl.edu).

Monetary values ($) are reported in US Dollars throughout the report.

PM_{10} consists of particulate matter less than 10 microns and greater than 2.5 microns. As PM2.5 is also estimated, the sum of PM10 and PM2.5 provides the total pollution removal and value for particulate matter less than 10 microns.

P**assenger automobile emissions** per mile (average) were based on dividing total 2002 pollutant emissions from light-duty gas vehicles (EPA, 2004). Average annual passenger automobile emissions per vehicle were based on dividing total 2002 pollutant emissions from light-duty gas vehicles by total number of passenger cars in 2002 (National Transportation Statistics, 2004).

Pollution removal Value is calculated based on the prices of $1136 per ton (carbon monoxide), $1264 per ton (ozone),$489 per ton (nitrogen dioxide), $159 per ton (sulfur dioxide), $4,871 per ton (particulate matter less than 10 microns and greater than 2.5 microns), $-12,018 per ton (particulate matter less than 2.5 microns).

Trees remove PM2.5 when particulate matter is deposited on leaf surfaces. This deposited PM2.5 can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to interesting results depending on various atmospheric factors. Generally, pollution removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

Structural value Value based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree).

Ton Short ton (U.S.) (2,000 lbs).

Appendix II. Comparison of Urban Forests

Sometimes it is useful to determine how a city compares to other areas. Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model. This comparison information is provided by the i-eco model and reporting.

Table 11. Total Tree Benefits in Other Areas

Area	Number of trees	Carbon Storage (tons)	Carbon Sequestration (tons/year)	Pollution Removal (tons/year)
Calgary, Canada	11,889,000	445,000	21,422	326
Atlanta, GA	9,415,000	1,345,000	46,433	1,662
Toronto, Canada	7,542,000	992,000	40,345	1212
New York, NY	5,212,000	1,351,000	42,283	1,677
Phoenix, AZ	3,166,000	305,000	35,400	1770
Baltimore, MD	2,627,000	596,000	16,127	430
Philadelphia, PA	2,113,000	530,000	16,115	576
Washington, DC	1,928,000	523,000	16,148	418
Albuquerque, NM	1,504,000	226,000	9,710	366
El Paso, TX	1,281,000	92,800	7,430	318
Boston, MA	1,183,000	319,000	10,509	284
Woodbridge, NJ	986,000	160,000	5,561	210
Minneapolis, MN	979,000	250,000	8,895	305
Syracuse, NY	876,000	173,000	5,425	109
Morgantown, WV	661,000	94,000	2,940	66
Moorestown, NJ	583,000	117,000	3,758	118
Las Cruces, NM	257,000	17,800	1,580	92
Eastern Colorado	251,000	71,900	2,200	77
Jersey City, NJ	136,000	21,000	890	41
Freehold, NJ	48,000	20,000	545	21

Table 12. Per-Acre Values of Tree Effects in Other Areas

Area	Number of Trees	Carbon Storage (tons)	Carbon Sequestration (tons/year)
Morgantown, WV	119.7	17.0	0.53
Atlanta, GA	111.6	15.9	0.55
Calgary, Canada	66.7	2.5	0.12
Woodbridge, NJ	66.5	10.8	0.38
Moorestown, NJ	62.0	12.5	0.40
Syracuse, NY	54.5	10.8	0.34
Baltimore, MD	50.8	11.5	0.31
Washington, DC	49.0	13.3	0.41
Toronto, Canada	48.3	6.4	0.26
Freehold, NJ	38.5	16.0	0.44
Boston, MA	33.5	9.0	0.30
New York, NY	26.4	6.8	0.21
Minneapolis, MN	26.2	6.7	0.24
Philadelphia, PA	25.0	6.3	0.19
Albuquerque, NM	17.8	2.7	0.11
Jersey City, NJ	14.3	2.2	0.09
Phoenix, AZ	12.9	1.2	0.14
El Paso, TX	12.7	0.9	0.07
Eastern Colorado	12.1	3.5	0.11
Las Cruces, NM	9.1	0.6	0.06

Appendix III. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are [Nowak, 1995]:

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities [Nowak, 2000]. Local urban management decisions also can help improve air quality.

Table 13. Urban Forest Management Strategies to Improve Air Quality

Strategy	Result
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix IV. Species Distribution and Botanical Names

Table 14. Species Distribution and Botanical Names

Common Name	Species	Percent Population	Percent Leaf Area	Importance Value
Afghan pine	*Pinus eldarica*	11.81	26.27	38.08
Desertwillow	*Chilopsis linearis*	17.98	11.72	29.70
Italian cypress	*Cupressus sempervirens*	15.80	1.53	17.33
Velvet ash	*Fraxinus velutina*	4.48	12.76	17.24
White mulberry	*Morus alba*	1.67	11.36	13.03
Siberian elm	*Ulmus pumila*	4.03	8.16	12.19
Black locust	*Robinia pseudoacacia*	3.94	4.61	8.55
Honey mesquite	*Prosopis glandulosa*	4.88	3.47	8.35
Chaste tree	*Vitex agnus-castus*	6.22	2.11	8.33
Chitalpa	*Chitalpa tashkentensis*	3.45	3.90	7.35
Oriental arborvitae	*Platycladus orientalis*	2.78	1.28	4.06
Live oak	*Quercus/live virginiana*	1.79	2.08	3.87
Purpleleaf plum	*Prunus pissardii*	2.24	0.96	3.20
London plane	*Platanus x acerifolia*	0.76	2.34	3.11
Pinyon pine	*Pinus edulis*	1.79	0.58	2.37
Willow spp	*Salix*	0.45	1.78	2.23
Neomexican elderberry	*Sambucus caerulea v mexicana*	1.79	0.39	2.18
Ocotillo	*Fouquieria splendens*	1.34	0.73	2.07
Texas red oak	*Quercus texana*	1.52	0.49	2.01
Mexican fan palm	*Washingtonia robusta*	1.66	0.23	1.88
Common crapemyrtle	*Lagerstroemia indica*	1.52	0.06	1.59
Cottonwood spp	*Populus*	0.45	0.94	1.39
Yaupon	*Ilex vomitoria*	0.90	0.31	1.20
Torrey yucca	*Yucca torreyi*	0.90	0.26	1.15
Raywood ash	*Fraxinus angustifolia 'Raywood'*	0.90	0.15	1.04
Soaptree yucca	*Yucca elata*	0.97	0.07	1.04
Northern white cedar	*Thuja occidentalis*	0.45	0.53	0.98
Oak spp	*Quercus*	0.76	0.10	0.86
Creosote bush	*Larrea tridentata*	0.45	0.36	0.80
Bur oak	*Quercus macrocarpa*	0.45	0.16	0.61
Eve's needle	*Yucca faxoniana*	0.45	0.12	0.57

Common Name	Species	Percent Population	Percent Leaf Area	Importance Value
Tree of heaven	*Ailanthus altissima*	0.45	0.08	0.53
Shumard oak	*Quercus shumardii*	0.45	0.04	0.49
Evergreen euonymus	*Euonymus japonica*	0.45	0.01	0.45
Pine spp	*Pinus*	0.07	0.06	0.13
Chinese pistache	*Pistacia chinensis*	0.02	0.01	0.03

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