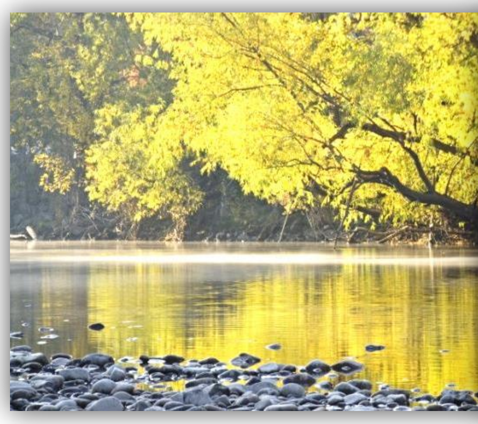
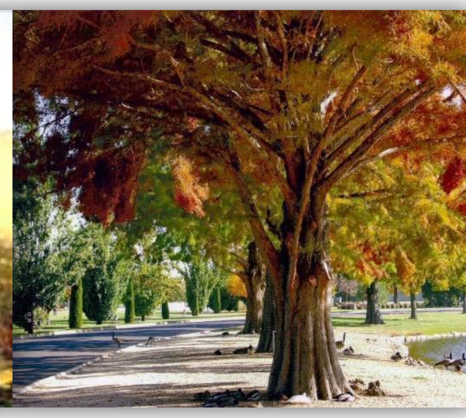
TREASURE VALLEY URBAN TREE CANOPY ASSESSMENT

MAY 2013





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Executive Summary

The Treasure Valley's urban forest is comprised of trees, gardens, green spaces and other natural areas. This urban tree canopy provides a myriad of benefits making our communities cleaner, safer and healthier while reducing the costs associated with many services. Managing, monitoring, and enhancing this important resource is critical to sustained economic development and environmental health.

The Treasure Valley (TV) Urban Tree Canopy (UTC) Assessment and Report brings together data from two complimentary studies to evaluate and understand the extent and value of the region's trees. The data and tools produced enable managers to develop strategies for community development, air quality enhancement, energy conservation, stormwater management, and community forest management. See **Project Background and Major Findings** (pages 2-4).

The assessment utilizes field-based measurements and Geographic Information Systems (GIS) to provide a benchmark of the urban tree population, land cover, and the value of the current and potential future urban forest. See **Project Fundamentals** (page 5).

A detailed land cover map for the Treasure Valley reveals nearly 10% average tree canopy. This data layer is central to the assessment and analysis tools and useful for numerous other applications. See **Land Cover Mapping and Urban Tree Canopy Analysis Results** (pages 6 & 22).

This report defines and quantifies various environmental and economic benefits of the region's tree canopy, known as ecosystem services, focusing on air quality, energy use, stormwater, and carbon sequestration. See **Ecosystem Services Analysis and Results** (pages 10 & 33).

The dynamic modeling tools developed for this project allow planners and managers to envision and plan their desired future urban forest. With these tools, users identify and prioritize strategic tree planting areas based on management objectives, and create alternative designs and cost/benefit scenarios at a regional-scale or for specific sites. See **Tools for Strategic Canopy Development Scenarios** (pages 17 & 39).

Suggested tree canopy cover goals are provided for the region and for each community based on GIS methods and a Canopy Calculator tool. Broad recommendations relate to future land cover and UTC assessments, ways to use the data and tools to target and maximize specific tree benefits, and next steps for the project core team. See **Recommendations for Implementation** (pages 47-48).

Though the Treasure Valley urban forest is relatively young, it nonetheless provides substantial benefits that can be quantified, monetized, forecasted and enhanced over time with proper planning and management. To maximize the function and value of the urban forest resource, it is critical to target canopy increases strategically and to educate policymakers and citizens about the benefits of urban tree canopy.

Project Background

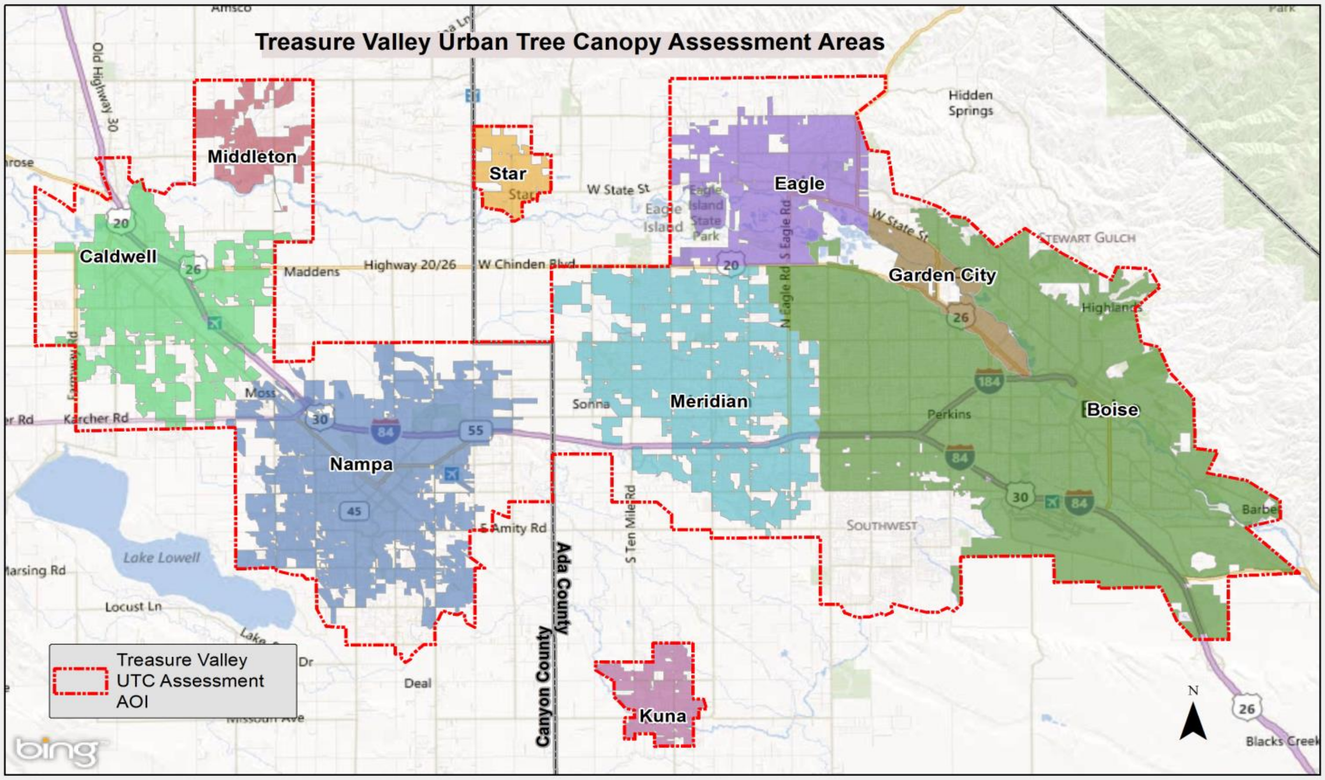
Idaho's Treasure Valley is located in the southwestern region of the state, an arid valley on the western edge of the great basin and the intermountain west characterized by dryland and irrigated agriculture, and framed between the Boise foothills, Boise River and Snake River. The project area spans two counties (Ada and Canyon), nine municipalities (including the state capitol, Boise) and a population of over 600,000 people—nearly 40% of the state's population. Communities within the Treasure Valley provide a significant percentage of the state's industry and business, critical to the economic vitality of this region. Planners, managers and industry are faced with a number of challenges as they focus on growing healthy and sustainable communities; including attainment of air quality standards (in particular ozone and particulates), stormwater management, energy use, economic development and planned growth—all of which are related to ecosystem health and the region's tree canopy.

In 2009, a core team of partners representing many different professions came together to discuss opportunities for addressing these challenges through strategic management and development of tree canopy in the Treasure Valley. This team, under the leadership of the Idaho Department of Lands (IDL), developed a proposal and secured funding through the USDA Forest Service (USFS) State & Private Forestry (S&PF) Western Competitive Resource Allocation Program for a Treasure Valley Urban Tree Canopy Assessment.

This two-part assessment includes a field-based sampling inventory of 250, one tenth (1/10) acre plots throughout the 266 square mile study area (January 2013 i-Tree Ecosystem Analysis of the Treasure Valley—Appendix E) and a geospatial Urban Tree Canopy Assessment[1]. The project area (Area of Interest, or AOI) for this assessment encompasses nine municipalities—Middleton, Caldwell, Nampa, Star, Kuna, Meridian, Eagle, Garden City and Boise and adjacent developed or rapidly developing areas. It includes both public and private lands.

[1] i-Eco is a US Forest Service Program designed to calculate benefits of tree canopy over large areas, utilizing the best available science and research information. An Urban Tree Canopy Assessment uses geographic information systems to identify and analyze land cover composition and tree canopy spatially, and model future scenarios.

Figure 1—Study Area: This assessment examined urban trees and associated benefits in the Treasure Valley area of interest (red boundary) and nine municipalities in Canyon and Ada Counties.



This report is a culmination of the Treasure Valley Urban Tree Canopy (UTC) Assessment and brings together both assessments, using a complete **Urban Forest Assessment Approach**—integrating top-down (remote sensing/GIS UTC Assessment) and bottom-up (field-based i-Tree Eco analysis) approaches to measure land cover, tree canopy and other green infrastructure, and associated ecosystem services. The products of this assessment include tools and resources that planners and managers can use for strategic management and development of urban tree canopy in the Treasure Valley. The products include: (1) A complete analysis of Land Cover and Urban Tree Canopy; (2) Ecosystem Benefits Analyses, including: air quality, energy, stormwater, and carbon; (3) GIS-based and other tools to model strategic tree canopy development scenarios; and (4) a training for Treasure Valley Canopy Partners on use of these tools to accomplish their management objectives.

The Treasure Valley UTC Assessment provides data and tools to better understand and enhance the quality and value received from its urban forest. The products support developing and monitoring tree canopy goals, data-driven management plans, refinement of landscape ordinances, and foster a greater understanding of urban tree canopy benefits (ecosystem services) and resulting opportunities for strategic integration into policy and planning processes throughout the Treasure Valley.

Major Findings

- **Tree Canopy:** Tree cover averages 10% in the Treasure Valley (TV) project area based on 2011 imagery, higher than the estimate of 7% from i-Tree Eco. Garden City and Boise have the highest canopy cover at 20% and 16% respectively while Middleton is lowest at 5%.
- **Neighborhoods:** Boise's Harrison Boulevard neighborhood averages 41% canopy cover, demonstrating that high tree cover in the TV is possible on certain land uses over time.
- **Tree Planting:**
  - Irrigated turf grass areas comprise 21% of the region excluding agricultural lands, golf courses and sports fields. An increase in tree canopy covering just half of this land would double regional tree canopy.
  - Parking lots cover 5,700 acres (3%) of the study area. 35,621 potential planting sites are within 50-feet of parking lots, which could add 600 acres of canopy cover, greatly reducing the urban heat island effect, ozone formation, and stormwater runoff.
- **Air Quality:**
  - Urban trees remove 581 tons of air pollutants annually—less than 1% of the region's air pollution. Even so, the value of this air quality benefit in reduced adverse human health impacts exceeds $7 million annually.
  - There are 60,737 potential planting sites along major road corridors and near parking lots where concentrations of pollutants are high. If all of these sites were planted in 2013, over a 50-year period, 1,708 tons of air pollutants would be removed, valued at $21.5 million.
- **Energy Conservation:**
  - A large tree on the west side of a residential home can save up to $48 per year in electricity & natural gas use.
  - 264,454 (52%) of potential planting locations in TV are within 50' of residential buildings, suggesting that opportunities to plant trees for energy efficiency can provide significant savings. Nearly half of these (110,692 planting spaces) are on the west side of homes where trees provide the greatest summer cooling benefit.
- **Stormwater:**
  - TV tree canopy mitigates 125 million gallons annually saving $1.1 million in stormwater infrastructure costs; in Boise, the benefit is 54 million gallons valued at $485,500.
- **Land Use:**
  - Nearly 2/3 of all tree canopy is located in residential areas based on an average of 17% tree cover. Nearly half of all available planting areas are also on residential lots.
  - Commercial land has just 6% canopy cover and 6,100 acres of parking lots

Project Fundamentals

In this section, methods and additional supporting information are presented for the main components and products of the Treasure Valley UTC Assessment: ***Land Cover Classification, Urban Tree Canopy (UTC) Assessment, Ecosystem Services Analysis, Tools for Strategic Canopy Development Scenarios, and Training***.

Urban Forest Assessment Approach

To develop budgets, urban forest management plans, and progressive policies, natural resource managers need to know what they have in order to effectively manage it. This is accomplished through periodic inventory, assessment, and analysis of the vegetation resource. The Phase-1 i-Tree Eco study (2011) and Phase-2 Treasure Valley UTC Assessment (2013) provide this information in a complete urban forest assessment approach combining top-down and bottom-up methods.

Unique to this study is the integration of i-Tree Eco results in conjunction with the geospatial data. With this approach, it is possible to map the spatial distribution of current and future ecosystem services related to canopy cover. Throughout this section, methods are provided to illustrate how each product builds upon and informs the next, ultimately flowing into the final assessment products, report, tools, and training (see Figure 2 below).

Project Fundamentals outline what was done, why, and how managers can use the products.

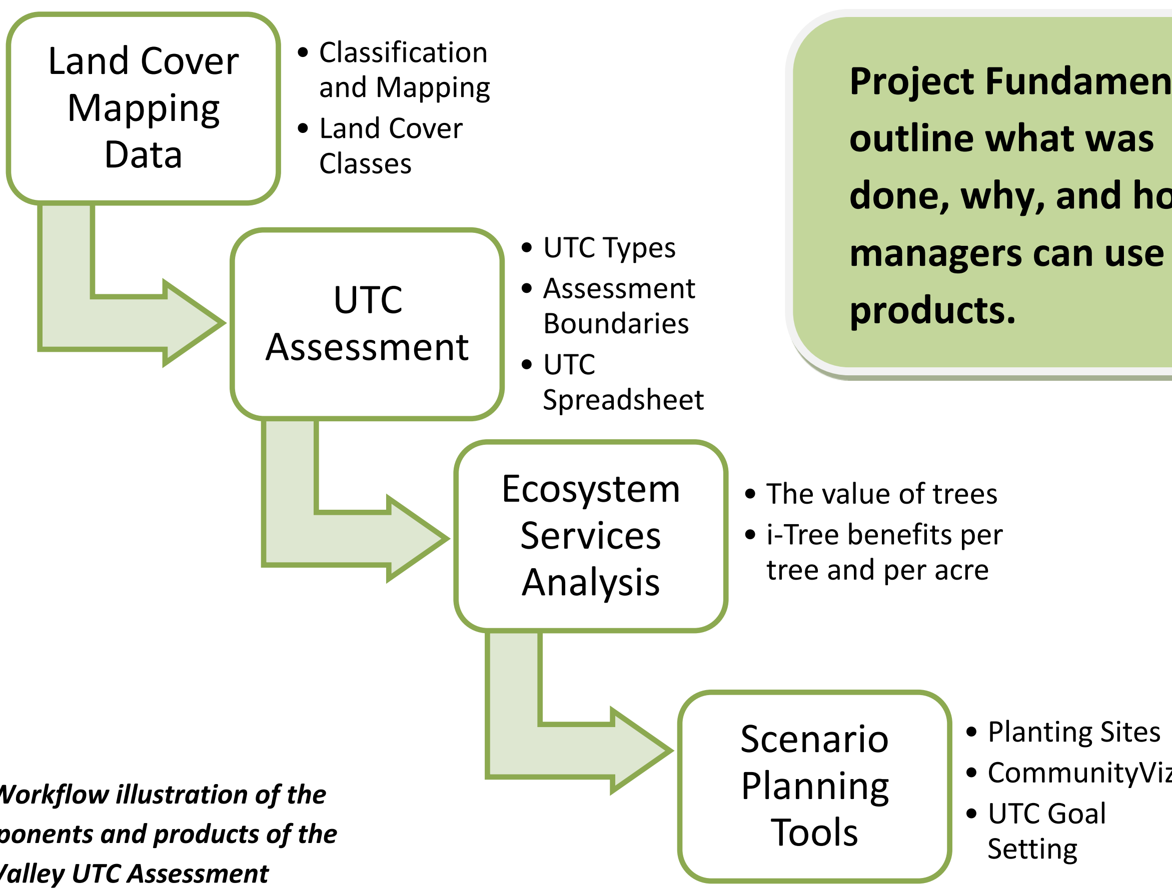


Figure 2. Workflow illustration of the main components and products of the Treasure Valley UTC Assessment

Land Cover Classification and Mapping

Land cover classes were mapped from 2011, 1-meter spatial resolution multispectral aerial photography using object-based image analysis (OBIA) classification techniques and digitized GIS layers. Features mapped through OBIA include canopy, irrigated/non-irrigated grass areas, bare soil, and an impervious surfaces class. Plan-It Geo used ~90,000 existing building polygons and digitized ~130,000 more from county aerial ortho imagery. Parking lots were mapped using a GIS model where building and road area was removed from the base impervious layer, clipped to commercial/industrial parcels, and limited based on a minimum polygon size. Existing and newly digitized water features were also incorporated into the final 9-class land cover data.

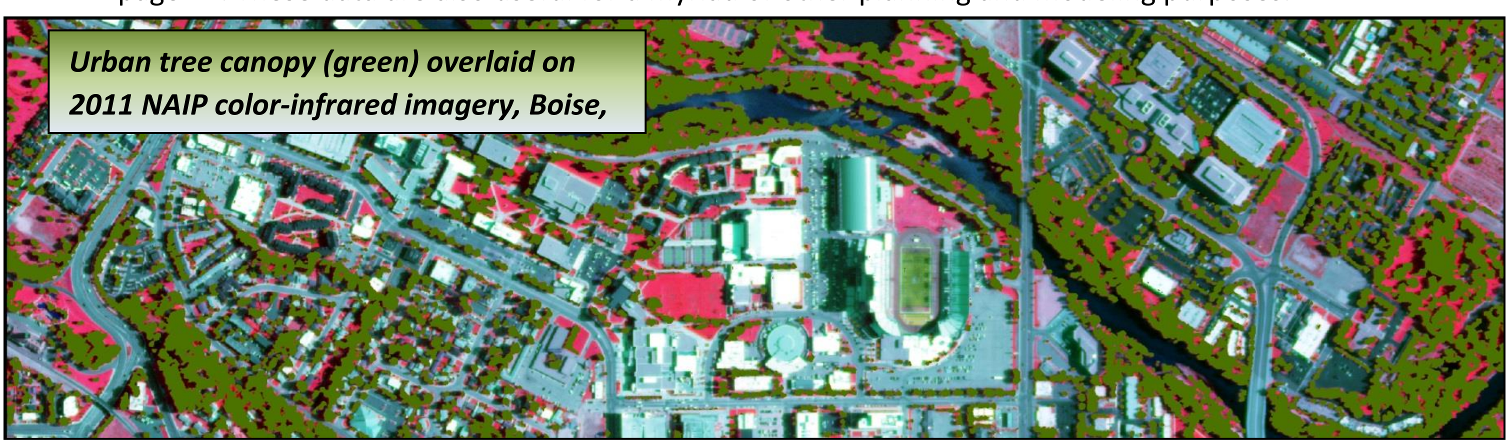
How Land Cover Classes were used in the TV UTC Assessment

- ***Tree Canopy:*** Allows analysis of ecosystem benefits and development of citywide planting goals
- ***Grass & Open Areas:*** Provides data on possible planting areas and planting prioritization
- ***Parking Lots:*** Used to identify strategic tree planting areas for maximum environmental and economic benefit
- ***Roads, Buildings, Other Impervious Surfaces, and Water:*** Eliminates areas that are unsuitable for tree planting in the UTC assessment metrics

Further details on the classification process, Quality Assurance / Quality Control, and an accuracy assessment matrix are in Appendix A. The final land cover classes include:

- 4 Vegetation Classes: deciduous and coniferous tree canopy, irrigated vegetation, non-irrigated vegetation
- 4 Impervious Surfaces Classes: roads, parking lots, building footprints, and other impervious areas
- 2 “Other” Classes: Bare Soil/Dry Vegetation and Water

The final 9-class land cover data serves as the baseline input for UTC assessment statistics, creation of potential planting locations, and modeling of ecosystem services, all of which inform the scenario planning tools. Summary statistics are presented in the Results section starting on page 21. These data are also useful for a myriad of other planning and modeling purposes.



Urban tree canopy (green) overlaid on 2011 NAIP color-infrared imagery, Boise,

Urban Tree Canopy (UTC) Types

Land cover classes were grouped into UTC Types for the assessment. UTC types categorize the landscape so that metrics can be summarized across spatial scales consistently for different users and applications. These metrics can be used to monitor land cover and changes in the urban forest over time and to target land uses, neighborhoods, natural areas, or individual properties for tree planting activities and/or policy implementation.

UTC Types assessed in this Report:

- ***Existing UTC*** is tree canopy from forests and individual trees when viewed and mapped from above.
- ***Possible Planting Areas (PPA)—Vegetation*** is the total area of grass and open space where tree canopy does not exist and it is biophysically possible to plant trees. For the TV UTC assessment, sports fields and other grass areas unsuitable for tree planting were removed from PPA—Vegetation.
- ***Possible Planting Areas—Impervious*** is the total area of hardscape surfaces that contribute to stormwater runoff where establishing tree canopy is most feasible (e.g. parking lots, etc.)
- ***Unsuitable UTC*** is the combination of buildings, roads, water and other areas where it is not feasible to plant trees (sports fields, golf course fairways & greens, airport grounds etc.)

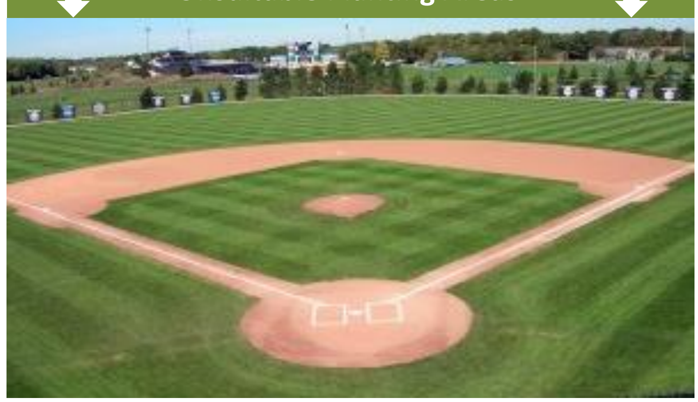
UTC types were mapped across GIS boundaries, described next. From the city to the parcel-level, the area and percent of these UTC types were calculated for map-making and summarized in Excel.

Existing Urban Tree Canopy

Planting Areas Grass/Open Space

Planting Areas Impervious Surfaces

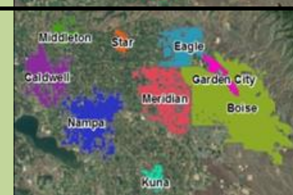
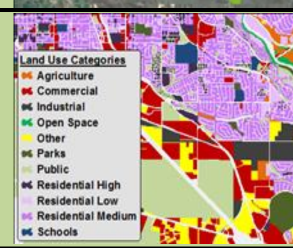
Unsuitable Planting Areas



Urban Tree Canopy (UTC) Assessment Boundaries

Assessment boundaries provide geographic units linked to where we live, work and play. Metrics for UTC Types are assessed for the GIS boundaries in Table 1. These summaries provide data for resource managers and planners at different spatial scales, and the resulting maps, tools and other products based on this information can be used for targeted planting initiatives and outreach campaigns.

Table 1. Assessment boundaries for the Treasure Valley UTC Assessment

Assessment Boundary	# of Types or Features	Description	Map
Project Area of Interest (AOI) (266 sq. miles)	1	Treasure Valley Urban Area	
City Limits	9	City limits of the 9 cities within the project AOI: Boise, Caldwell, Eagle, Garden City, Kuna, Meridian, Middleton, Nampa and Star	
Boise Neighborhood Associations	36	Registered neighborhoods within the city of Boise	
Land Use	12	**Land Use Types Assessed:** Agriculture, Commercial, Industrial, Open Space, Parks, Public Land, Residential High-Density, Residential Medium-Density, Residential Low-Density, Schools, Rights-of-Way, and Other	
Census Blocks	13,184	2010 U.S. Census provides demographic data at the tract, block group, and block level. The most detailed 'block' level was used for this project and tools.	
Street Rights-of-Way	13,311	The public rights-of-way (ROW) specifically along streets. For each city, the ROW was broken into smaller segments by street name.	
Parcels	206,130	Tax lots from the Ada and Canyon counties' assessors property database	

Assessing UTC at Multiple Scales

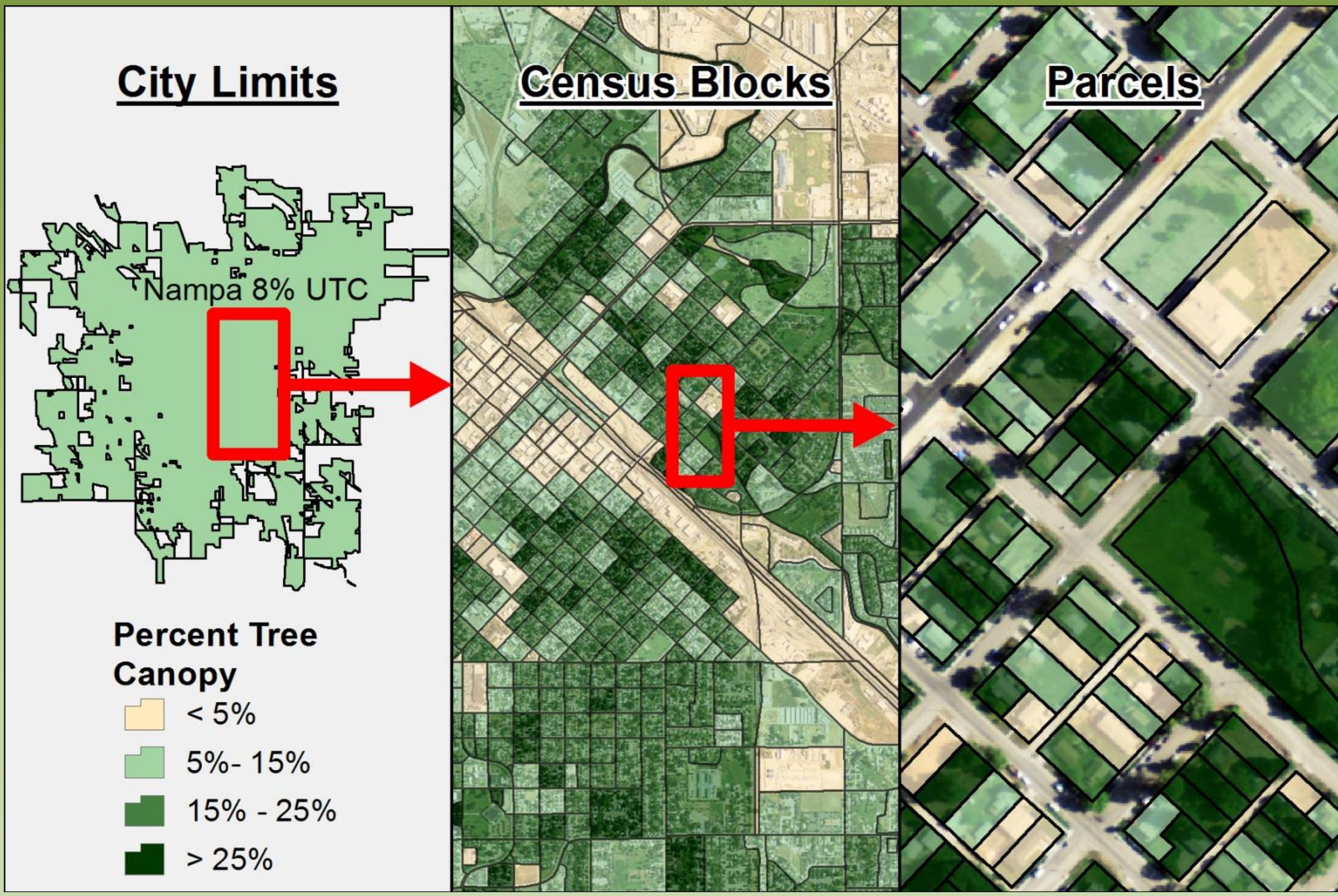


Figure 3. "Drilling down" with UTC assessment boundaries from citywide to parcel scale

Managing UTC Data at Multiple Scales

- ✓ Larger assessment boundaries (e.g. City, County, Neighborhoods) are important for understanding regional trends and for cooperative goal setting.
- ✓ Medium-sized assessment boundaries (Census Blocks, Land Use) are useful for viewing general distribution of UTC and PPA in TV and for identifying target areas for urban forest management activities.
- ✓ Small assessment boundaries (Parcels, ROW) are useful for engaging and initiating on-the-ground forest management actions such as planting projects and preservation ordinances with individual landowners.

Ecosystem Services Analysis

Urban forests are an integral part of the character of the Treasure Valley. While trees are often appreciated for their aesthetic appeal, the true *benefits* of trees and forests, contributing to the health and vitality of residents' daily life, is often unknown or under-valued. This report quantifies some of the benefits of urban trees, referred to as "ecosystem services." While the net benefits of urban trees are usually positive, costs are also part of this study's ecosystem service evaluation and scenario tools for managers.

Current and future values were estimated for the following four ecosystem service types:

- *Air Quality*—Trees naturally remove pollutants and lower air temperature
- *Energy*—Trees help reduce energy consumption by shading buildings in summer and blocking winter winds
- *Stormwater mitigation*—Trees intercept stormwater, reducing runoff and filtering out pollutants that would otherwise enter rivers and lakes
- *Carbon sequestration and storage*—Through photosynthesis, trees absorb atmospheric carbon and use it for new growth (stems, branches, roots and leaves), acting as a natural carbon sink

Ecosystem services values provided by trees in the Treasure Valley study area were analyzed using the i-Tree Eco model and two main analysis methods:

1. ***Per acre*** benefits were created by tying total ecosystem service values from the 250, 1/10th acre i-Eco plots with existing UTC for the region and per city.

2. **Per tree** benefits at five-year age increments for 12 key tree species (see Appendix B for a description of species selection) were estimated by modeling hypothetical i-Eco plots.

Urban forests in "The City of Trees" provide many ecosystem service benefits, and enhance the natural beauty of Boise and each community in the Treasure Valley

Per acre values provide a mechanism for evaluating ecosystem services at multiple scales. With this information, managers and planners are able to place a quantified value on an area of land based on UTC. Future ecosystem service values are reported by expanding per acre values to anticipated UTC percentages for the study area and each city.

Per tree values provide the foundation for using planning tools to measure scenario-based ecosystem service values. Per tree values allow managers and planners to attribute values to individual planting sites and plans through the use of the CommunityViz planning tools (see *Modeling Tools for Strategic Canopy Development Scenarios* on pages 19 & 40).

The remainder of this section provides the following information about each ecosystem service type assessed in this study:

- How is each ecosystem service type is related to trees
- How i-Eco evaluates each ecosystem service type
- How and why i-Eco results are reported in this assessment
- What managers and planners can accomplish with the results and tools
- The key assumptions and limitations which should be considered

How are UTC types and Ecosystem services related?

- *Existing UTC* is used to derive per-unit-area (e.g. acre) ecosystem service values
- *Possible Planting Area—Vegetation* is used to create planting sites tied with tools for estimating per-tree ecosystem services
- *Possible Planting Area—Impervious* identifies areas in need of planting for increasing green space and ecosystem service generation
- *Unsuitable UTC areas* are prohibitive to planting. Adjacent or surrounding areas can be targeted to offset ecosystem service losses from these areas.

Air Quality

At 40 years of age, the average tree:

- Will remove about **2 pounds** of air pollutants each year, saving **$13.26**
- Will have removed **35 pounds** in its life to date, saving **$211.93**

Air quality is one of most critical issues in the Treasure Valley. This area has exceeded attainment limits set by the Environmental Protection Agency (EPA) for Particulate Matter (PM) and is in danger of going non-attainment for ozone (O3) in the near future. A non-attainment designation can lead to compromised public health, diminished economic growth, new and costly regulations, and a potential loss of federal highway funds.

The three main effects of urban trees that lead to improved air quality are:

(1) Lower air temperatures resulting from shade and latent heat absorption, which reduces ozone formation and smog.

(2) Air is "cleansed" through the direct removal of a variety of pollutants.

(3) Indirectly, shade from trees reduces the amount of energy used for cooling, therefore limiting pollutants emitted from power plants.

Some tree species emit biogenic or naturally occurring volatile organic compounds (VOCs) that can contribute to ozone formation. However, in most cases the positive affects of these trees result in an overall reduction in ozone. Trees can substantially lower O3 production by blocking sunlight and lowering temperatures on surfaces that emit NOx and VOCs (asphalt, fuel tanks, buildings, etc.) which contribute to the formation of ground-level ozone.

I-Eco models apply a value to trees for their air pollution removal capacity based on several variables including climatic conditions, pollutant concentration (2005 calendar year), human population estimates, avoided human health issues[2], and vegetation composition in the study area. To understand how UTC may contribute to greater air quality, i-Eco model inputs were manipulated to simulate greater canopy cover in the region. Values associated with the absorption of six forms of pollution were summed to provide per-acre and per tree values for the Treasure Valley study area's urban forests and trees.

Estimated per-acre values are summarized for the Treasure Valley Study area and for each city in the table on page 34, demonstrating the contribution of trees toward better air quality, and benefits of expanded canopy cover in the future. Per tree values were used as inputs for the CommunityViz planning tools to allow managers, planners, and officials at the Idaho Department of Environmental Quality (ID DEQ) to evaluate direct benefits that will result from planting projects and changes in UTC.

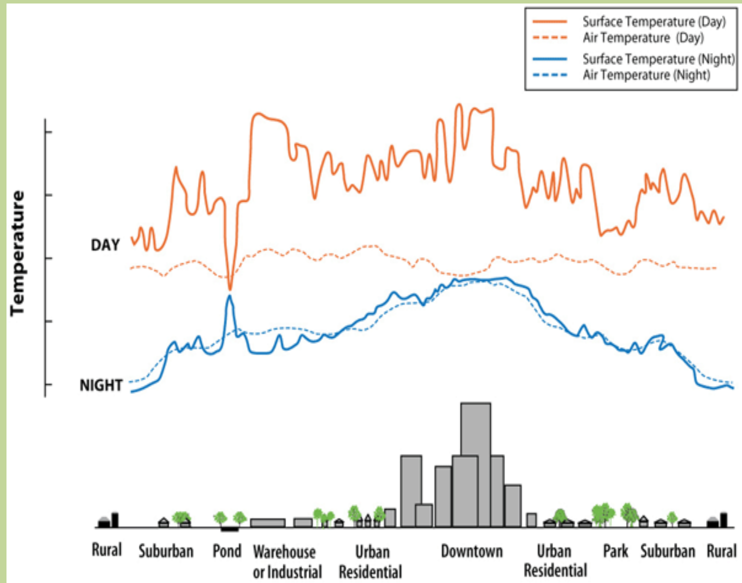
[2] Calculated using EPA's BenMAP program (http://www.epa.gov/air/benmap/)

The impact on air quality resulting from the manipulation of available canopy cover in the i-Eco model was limited by the size and immense air volume of the study area (see Appendix B for more details). Also, the i-Eco model does not reflect the spatially specific positive benefits of trees shading impervious areas and reducing negative *Urban Heat Island* impacts (see callout box below).

Urban Heat Islands

Impervious surfaces such as asphalt, concrete and other building materials transfer and reflect the sun's energy, creating thermal pockets near intensely urbanized areas. Shade provided by trees is the most effective strategy for mitigating the harmful effects of urban heat islands by reducing surface temperatures and helping to keep the air clean and safe to breathe.

http://www.epa.gov/heatisland/about/index.htm



Energy Use Impacts

At 40 years of age, the average tree:
(When planted on the west side of a home)

- Will **save a homeowner $39** on their heating & cooling costs this year
- Will have **saved a homeowner $771.59** in its life to date

Trees impact the energy consumption for buildings directly by providing cooling shade in summer and by blocking cold winter winds, reducing air conditioning and heating costs. Indirectly, trees reduce radiant heating from impervious surfaces such as asphalt, and provide evaporative cooling through their respiration processes. Energy use impacts are dependent on the relative proximity and direction of trees from buildings as well as their species and height.

Energy impacts reported by i-Eco reflect the building-tree interactions present within the sample plots, as well as local costs for both heating and cooling. While i-Eco results provide an estimate of energy impacts from urban trees, there is little information about what characteristics of trees provide the greatest benefits. i-Eco results were manipulated by creating hypothetical plots for 12 common tree species to measure the impact of tree placement and species on the energy use values associated with trees. i-Eco energy values were also compared with values created using the free web-based tool *i-Tree Design*[3] (see *Energy Use Results* on page 35).

Per-acre energy use savings based on existing and projected future canopy cover are summarized for the study area and for each city in the table on page 35, demonstrating the contribution of trees to energy savings. Per-tree energy use values are provided as inputs for CommunityViz planning tools, which can be used by managers, planners, and officials at Idaho Power to understand how trees impact energy consumption based on tree type and location relative to buildings and structures. Results can be used to create outreach and incentive programs to increase tree planting in locations that maximize energy conservation benefits. Additional information regarding the impacts of tree species and location are provided in *Recommendations* (page 48) and Appendix B.

The energy use impacts reported by i-Eco are based on prior research that may not directly reflect conditions within the Treasure Valley study area, but represent the best available science. Energy impacts depend on the specific location of trees relative to buildings and structures; the specific location of trees (not just more of them) is particularly important for increasing energy benefits.

Stormwater Mitigation

Trees and other vegetation help mitigate stormwater run-off by intercepting precipitation, naturally aerating soil increasing absorption, and through evapotranspiration from respiration processes.

At 40 years of age, the average tree:

- Will reduce stormwater runoff by **194 gallons** per year, a savings of **$1.73**
- Will have reduced stormwater runoff by **3,202 gallons** in its life to date, saving **$28.48**

I-Eco incorporates climatic information in its modeling, including rain event length and intensity, to estimate the volume and cost of additional runoff that would occur in the absence of trees and shrubs. The table on page 37 summarizes the volume and dollar values for stormwater mitigation using per-acre values for the Treasure Valley study area and each city—for existing and future UTC scenarios. Planners and managers can use per-acre summaries to place a stormwater value on forested areas.

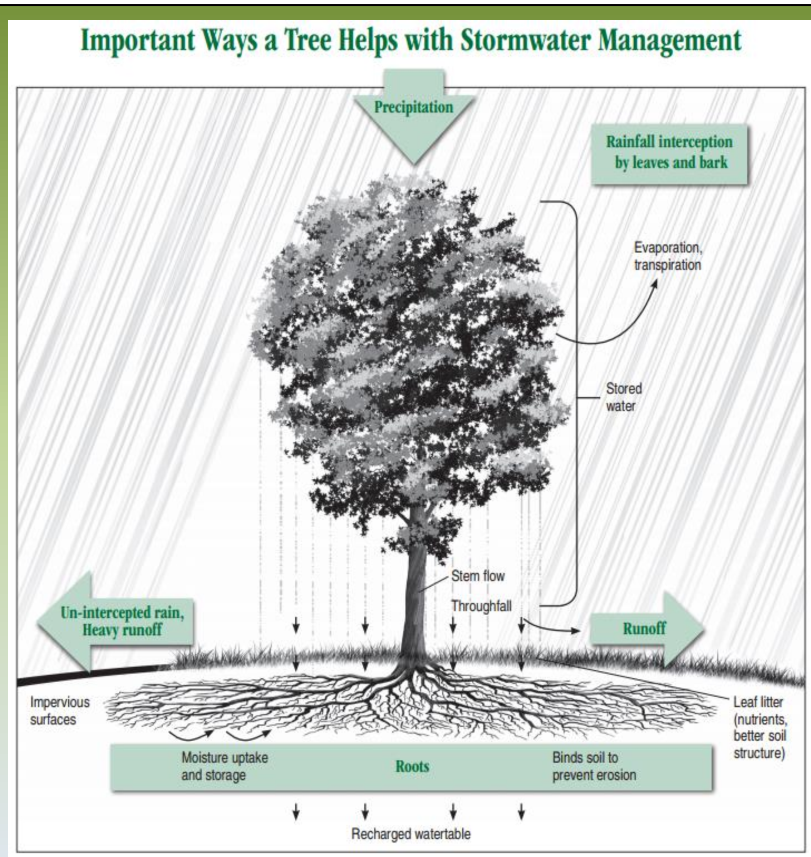
Per-tree stormwater mitigation values are used in the CommunityViz planning

[3] i-Tree Design is a free online map-based software that allows anyone to make simple estimations of the benefits of individual trees. Access the tool at http://itreetools.org/design.php.

tools for planting site modeling, allowing officials at the Ada County Highway District (ACHD) and municipalities to evaluate costs associated with reduced stormwater runoff from large impervious areas (such as the parking lot in the image on the previous page).

Additional benefits related to stormwater mitigation not captured in the i-Eco model include the filtration of pollutants by tree roots and the reduction of erosional forces caused by the direct impact of raindrops on exposed soil. In extreme rain events, benefits provided by trees can be exponential if reduced stormwater would have caused water damage in the absence of trees. While strategic placement of trees can maximize their benefits, this is not reflected in the i-Eco model.

How trees provide benefits through stormwater mitigation illustrated in the Arbor Day Foundation's Tree City USA Bulletin



Carbon Sequestration and Storage

At 40 years of age, the average tree:

- Will sequester **58 pounds of carbon** this year
- Will have sequestered **1,168 pounds of carbon** in its life to date

Carbon is a natural element and a major component of every organic material on the planet including natural gas, coal, gasoline and the woody material in trees. As these materials are burned to produce energy, carbon is released into the air raising atmospheric concentrations and contributing to the negative impacts to global climate.

i-Eco estimates the amount of carbon sequestered (i.e. carbon removed from the atmosphere during photosynthesis) and stored in trees as new growth. The table on page 38 uses per-acre values to summarize carbon sequestration and storage for the Treasure Valley study area and for each city based on current and future UTC scenarios. Per-acre values are also used in CommunityViz tools for estimating the impact of existing and new trees over large areas.

CommunityViz planting-site modeling tools use per-tree carbon sequestration and storage values, allowing users to identify direct benefits from specific planting plans.

Other Ecosystem Services Provided by Trees

Urban trees provide many ecosystem services including direct benefits, like those assessed in this study, and indirect benefits that are often more difficult to quantify and which are not included in this study. Reduced crime rates, fewer accidents, increased property values, wildlife habitat, pavement longevity from shade, erosion control along streams, and more retail dollars from shaded shopping areas have all been associated with a healthy urban forest. Managers, planners and citizens alike are encouraged to learn about all the ways trees enhance our quality of life every day. See i-Tree Resources at http://www.itreetools.org/resources/index.php and Appendix B for additional benefits of urban trees.

Trees provide many services and benefits that enhance the environment and local economies. The City of Boise was a reference city for the regionally specific modeling capabilities of the i-Tree Streets software program. i-Streets is a street tree management and analysis tool that uses inventory data and shows the annual dollar value of benefits provided by city street trees.

http://www.itreetools.org/streets/resources/Streets_Reference_Cities_Science_Update_Nov2011.pdf

Tools for Strategic Canopy Development Scenarios

Using the GIS-based land cover data and UTC metrics for different assessment boundaries, Plan-It Geo created tools to assist resource managers and planners accomplish their urban forestry, environmental, and community development objectives.

Methods used to develop the following tools are presented in this section:

- **Potential Tree Planting Locations**
- **Modeling Tools for Strategic Canopy Development Scenarios**
- **Urban Tree Canopy (UTC) Goal Setting**

Potential Planting Locations

Land cover data formed the basis for mapping potential tree planting locations. Planting sites were generated where adequate space exists to allow for tree planting and growth. To ensure realistic tree planting locations, several GIS overlays were applied to exclude areas where it is not feasible to plant trees, detailed below in Table 2.

Managers can use planting site data to prioritize planting efforts and forecast future canopy. Attributes were added to each GIS planting point so that locations can be queried by land use, existing UTC, proximity to highways, parking lots and buildings, and many other criteria.

Planting sites were used as inputs to scenario planning tools discussed in the next section.

Table 2 . Description of exclusions used in mapping potential planting sites.

Excluded GIS Layer	Geographic Rule Applied	Reasoning
Fire Hydrants (Boise only)	Buffer 8 feet	To avoid space conflicts between trees and hydrants
Street Intersections	Buffer 15 feet	To avoid line-of-site and other safety conflicts
Buildings	Buffer 5 feet	To avoid space conflicts between trees and buildings
Existing Tree Canopy	Buffer 10 feet	To allow room for existing trees to grow
Agricultural Land Use	Buffer 15 feet (inward) and subtract a “ring buffer” for any buildings (ring-shaped area that is between 5 and 50 feet from the building)	It is generally not reasonable to plant trees in agriculture fields, except in areas where agricultural activity is most likely not happening; around their edges (within the 15 ft inward buffer) and around any buildings (within the ring buffer)
Unsuitable UTC Class	Excluded entirely	This class specifically represents areas where it is not bio-physically feasible to plant trees. Examples of unsuitable areas: sports fields, golf course fairways & greens, airport runways.

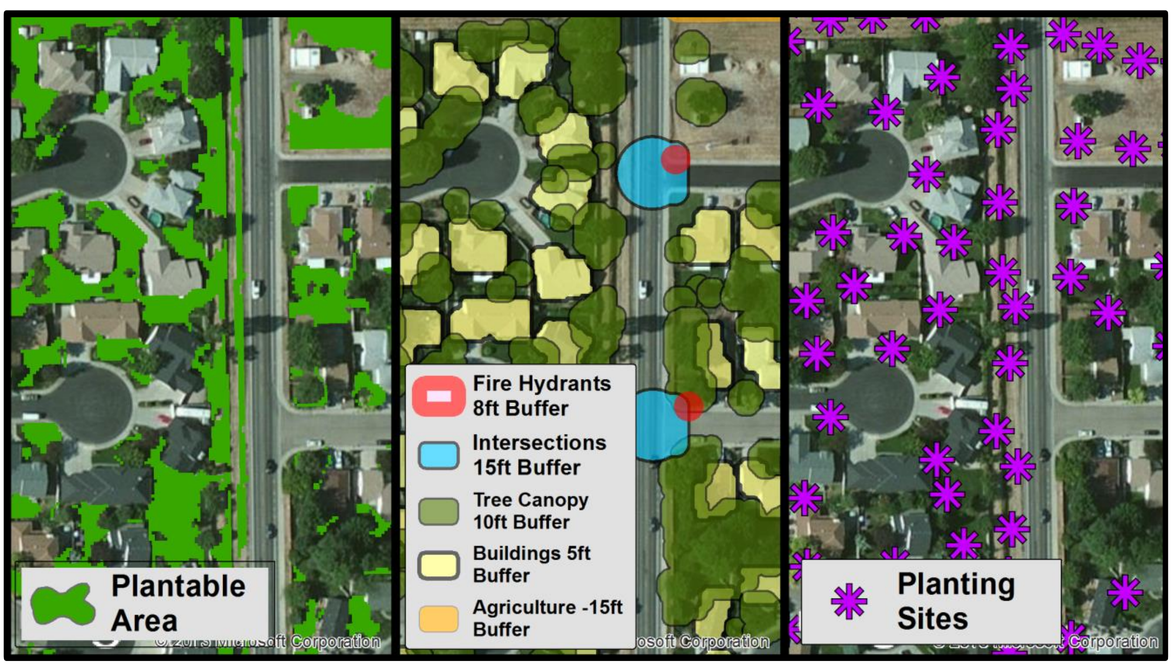


Figure 4. Inputs to the planting sites model and the resulting locations. The left frame shows plantable areas delineated from the remotely- sensed land cover data. The middle frame shows how local data were integrated to exclude certain areas from the plantable space. The right frame shows the resulting potential planting sites.

Modeling Tools for Strategic Canopy Development Scenarios

Plan-It Geo designed and created planning tools that model future ecosystem benefits based on user-based scenarios, for both increases in UTC and continued growth of existing UTC. CommunityViz (CV), an ESRI ArcGIS extension for land use planning by Placeways LLC, was selected as the scenario planning software.

The CV tools allow users to track, prioritize, and visualize planting opportunities and future ecosystem services—at the regional and city-level based on 2010 census blocks boundaries—or at the site-level with individual trees. Using i-Tree Eco inventory data and calculations, the tools model the urban forest ecosystem service benefits for air quality, energy, stormwater, and carbon.

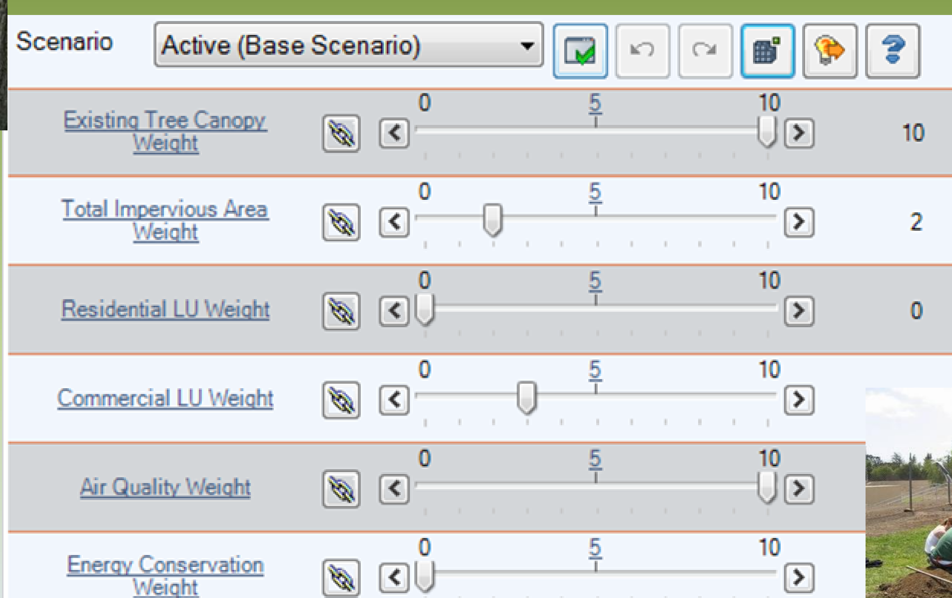
For resource managers to see the impacts of different planting and canopy cover scenarios, summary charts of ecosystem values (dollars and resource units) update "on-the-fly" in CV.

For example, Idaho DEQ can use the tools to prioritize planting in census blocks overlapping major roads and parking lots—those areas where air pollution concentrations are likely highest and benefits can be maximized. GIS layers and summary charts of a scenario quickly show the impact on improved air quality, specifically for particulate matter (PM) 2.5, PM 10 and ozone.

Similarly, Idaho Power can use the tools to prioritize planting near residential homes and forecast the potential energy impacts, and Ada County Highway District can target trees along major highways, parking lots, and riparian/floodplain areas for stormwater management benefits.

Within the Results and Products section (page 40) are three example scenarios using the CV tools. A complete user's guide and documentation for the tools is provided in Appendix C.

Planning tools use information collected about the region's urban forest (top left) to plan tree planting and care (bottom right)



UTC Goal Setting

To help facilitate regional and local Urban Tree Canopy goal setting, Plan-It Geo conducted a GIS-based ranking methodology known as the *75th Percentile Rule* (Poracsky and Lackner 2004) and developed a turn-key Microsoft Excel "Canopy Calculator" tool.

Parcels and census blocks were assessed by land use and percent canopy cover to identify potential canopy cover goals regionally, for each community, and by land use. By ranking parcels and census blocks based on their percentage of canopy cover, the canopy percent at the 75th percentile becomes the target. This represents the threshold where a quarter of areas have already achieved the target. The target percent canopy cover was averaged for parcels and census blocks and then rounded down to suggest a conservative goal. See pages 44-45 for results.

To complement the community goal setting process, Plan-It Geo also provided an Excel spreadsheet "Canopy Calculator" tool for the full study area and each for city, allowing users to assess the impact of tree planting on new canopy cover by land use types. An example of the plug-n-play Canopy Calculator tool is provided in Appendix C.

Treasure Valley Core Team Training Session

A hands-on full day technical training session for Core Team Partners was fundamental to the success and future implementation and outcomes from the Treasure Valley UTC Assessment. IDL, The Keystone Concept, and Plan-It Geo developed a training agenda (see Appendix D) and provided in-depth training on the GIS data products, ecosystem services analysis approach, and various tools in map, spreadsheet, and GIS-based format.

With regional forestry and natural resource partners having different levels of exposure to GIS tools, the training provided an opportunity for an organization's GIS staff to work closely with their forestry or natural resource professional(s). Additionally, more experienced Core Team partners were able to work with and assist others.

Particular emphasis was placed on the CommunityViz tools to encourage all partners to explore and fully utilize the canopy scenario planning models. Outcomes from training session are outlined in the Results section on page 46 and in the Recommendations & Implementation section on page 49.

Assessment Results & Products

The regional UTC data, reports, and other tools can help inform management recommendations, policies, partnerships, education, outreach, and funding strategies to maximize the functional benefits of tree canopy in addressing critical issues. Setting realistic goals collaboratively for different land uses and planning scales creates a shared vision, helping ensure resources are allocated effectively and adaptive management occurs over time.

To ensure UTC data and analyses are useful to planners, scientists and citizens on the ground, results in this project are provided in multiple formats and scales for various purposes. Different assessment boundaries are governed, owned, managed, and used in different ways by different groups. The boundaries used in the assessment tools for this project were selected to allow simulations of realistic urban forest management actions. The following sections present land cover, canopy cover, and planting potential in the full Area of Interest, then by city, neighborhood, census block, parcel, land use and rights of way boundaries, followed by results for current and future ecosystem services.

The **Summary and Conclusions** section on page 50 list the on-line locations of data, tools and project information.

How Are UTC Results Used?

- To set and implement canopy cover goals
- To assess ecosystem services benefits of urban trees
- To prioritize areas for tree planting and preservation
- To analyze and visualize opportunities to enhance the urban forest to meet multiple environmental, social, and economic goals
- To determine if land use policies and ordinances are achieving desired tree conditions
- To work with multiple, diverse partners to achieve and maintain goals

Land Cover Analysis Results

Regional Land Cover Results

Based on a GIS and remote sensing analysis of summer 2011 aerial photography, the chart below depicts the region's distribution of nine land cover classes. The map in Figure 6 on the following page illustrates the spatial extent of the land cover data used to produce the summary below.

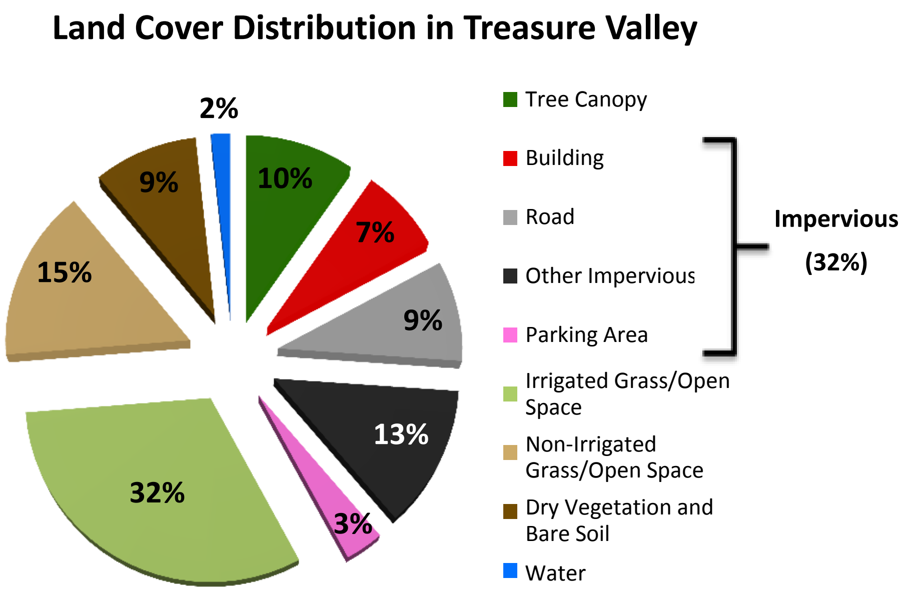


Figure 5. Land Cover Distribution in the Treasure Valley Study Area.

Land Cover Category	Acres
Tree Canopy	16,451
Building	12,741
Road	15,181
Other Impervious	21,547
Parking Area	5,689
Irrigated Grass/Open Space	53,778
Non-irrigated Grass/Open Space	25,999
Dry Vegetation and Bare Soil	15,779
Water	2,871
Total	**170,036**

Table 3. Regional Land Cover Distribution in Acres

Results for Municipalities

Land cover statistics were calculated for the nine cities in the TV region (see Appendix A).

An electronic MS Excel-based "UTC Spreadsheet" product was also provided for the TV AOI and each City. The second worksheet (tab) includes detailed acreages and percentages of land cover results.

Land Cover in Treasure Valley

Based on 2011 NAIP imagery

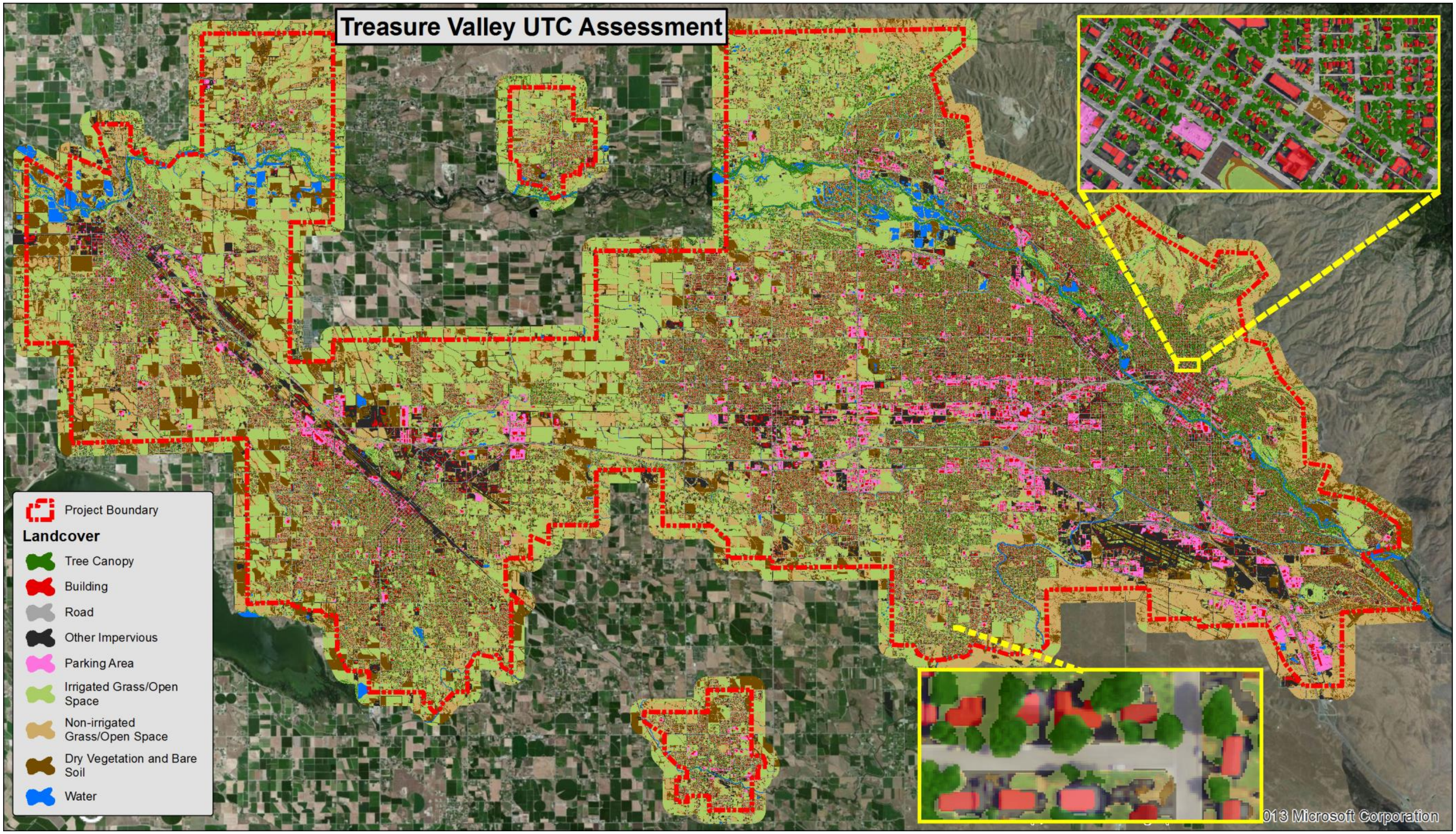


Figure 6. Complete 9 class land cover in the Treasure Valley, used as the base for the UTC assessment.

Urban Tree Canopy (UTC) Analysis Results

Regional UTC Results

Creation, growth, and preservation of urban tree canopy require a joint effort between private landowners who manage their own trees, and municipalities who manage public trees. In the Treasure Valley study area, approximately 24% of all tree canopy cover is located on land use categories under public management (see *UTC Results by Land Use* on page 31 for more information). Municipalities have the authority and responsibility to manage planting projects in public places such as in parks, along streets, and at schools. Municipalities can also enact tree management policies that limit or control how private trees are managed. It is important, therefore, to understand the urban tree canopy across ownerships in order to allocate forest management resources and efforts optimally.

Averaged across the entire project AOI, the region has 10% canopy cover and 40% additional land available for possible urban forest expansion.

Presented in Figure 7 below are the UTC assessment results for the study area including Existing UTC, Possible Planting Area (four types) and areas in which tree planting is Unsuitable.

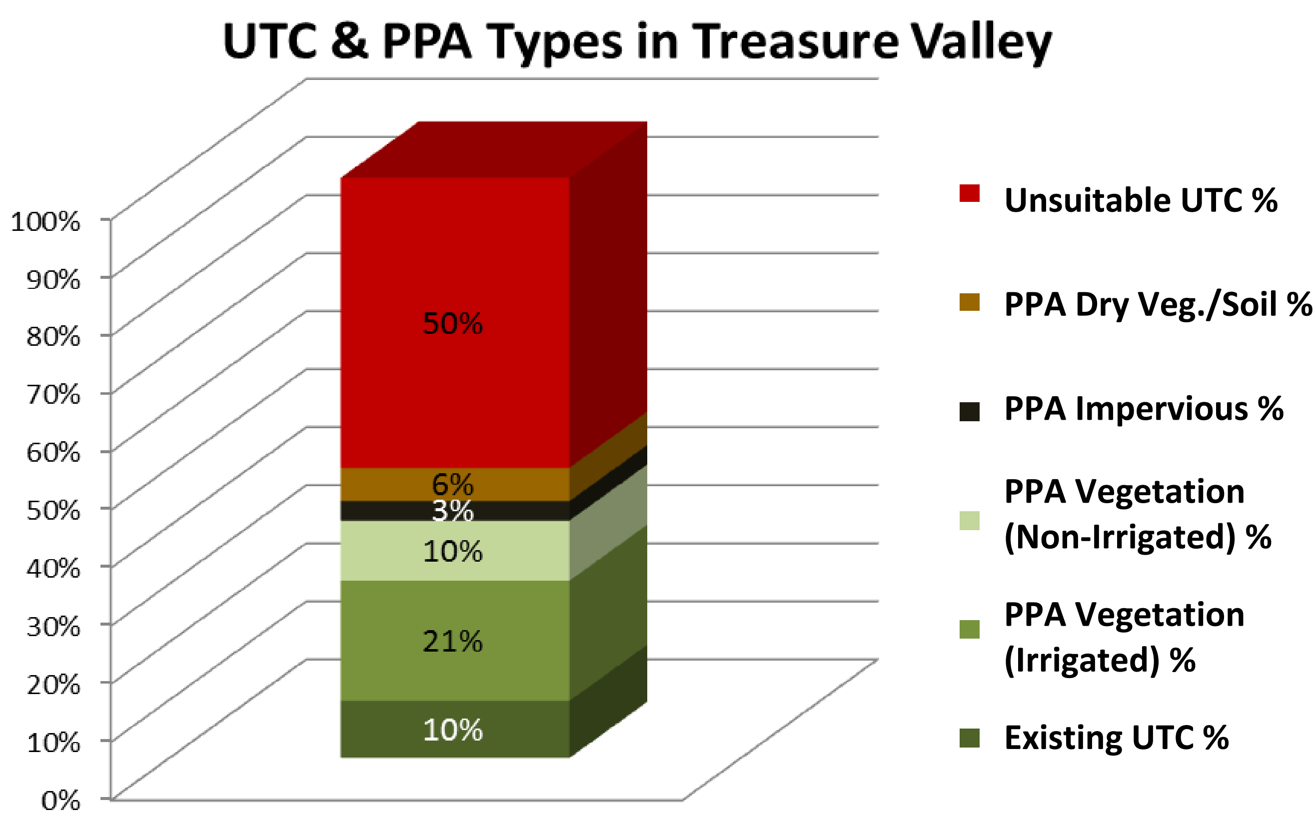


Figure 7. Regional UTC results by assessment type (percentages based on land area excluding water).

UTC Results for Municipalities

The same UTC metrics that were calculated for the project AOI were also done within the boundaries of each of the nine cities. Existing UTC percent in Treasure Valley's cities ranges from 5% in Middleton to 20% in Garden City as shown in Table 4 below.

Table 4. Comparison of UTC in Acres for Cities in the Treasure Valley.

City	Boise	Caldwell	Eagle	Garden City	Kuna	Meridian	Middleton	Nampa	Star	Total
Tree Canopy Acres	7,149	735	1,423	523	157	1,125	136	1,441	110	**12,801**
Tree Canopy %	16%	6%	16%	20%	6%	7%	5%	8%	6%	**10% (avg.)**

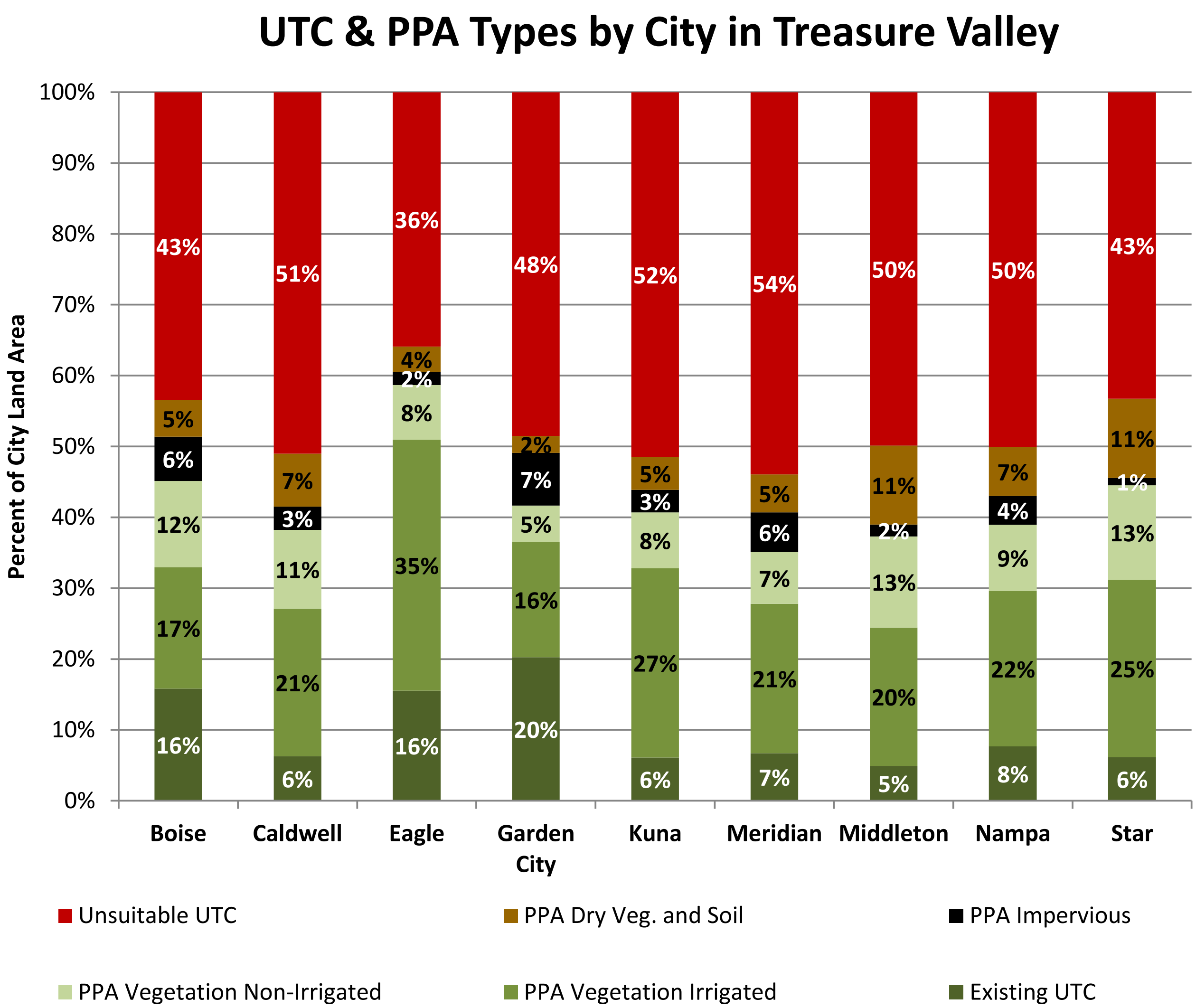


Figure 8. Comparison of UTC results for cities in the Treasure Valley.

UTC Results for Boise Neighborhood Associations

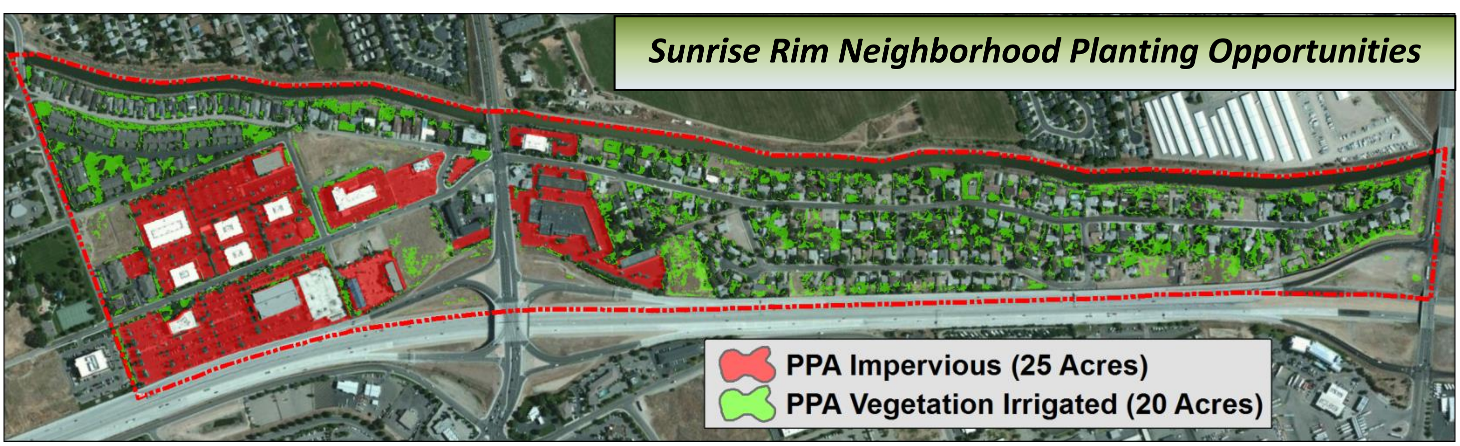
Neighborhoods are where many grass-roots policies and actions originate and are an appropriate target in which to focus urban greening initiatives. Neighborhoods Associations (NAs) in Boise are managed through cooperative planning between neighborhood residents and city officials.

Assessing UTC metrics at the neighborhood scale can help community groups and managers assess existing canopy and planting areas. Conversely, at the parcel level UTC metrics can demonstrate to homeowners the value of existing and potential new canopy benefits, such as a decrease in cooling and heating costs.

Boise Neighborhoods

- Existing UTC ranged from 4–41% with 21 out of 36 neighborhoods above 20% average tree cover
- Possible Planting Area (PPA) ranged from 14–77%
- The Pioneer neighborhood has 31% “PPA Impervious” (parking lot area)

The map on the following page shows UTC metrics calculated for the thirty-six registered neighborhood associations in Boise, with complete results in Figure 10 on page 28.



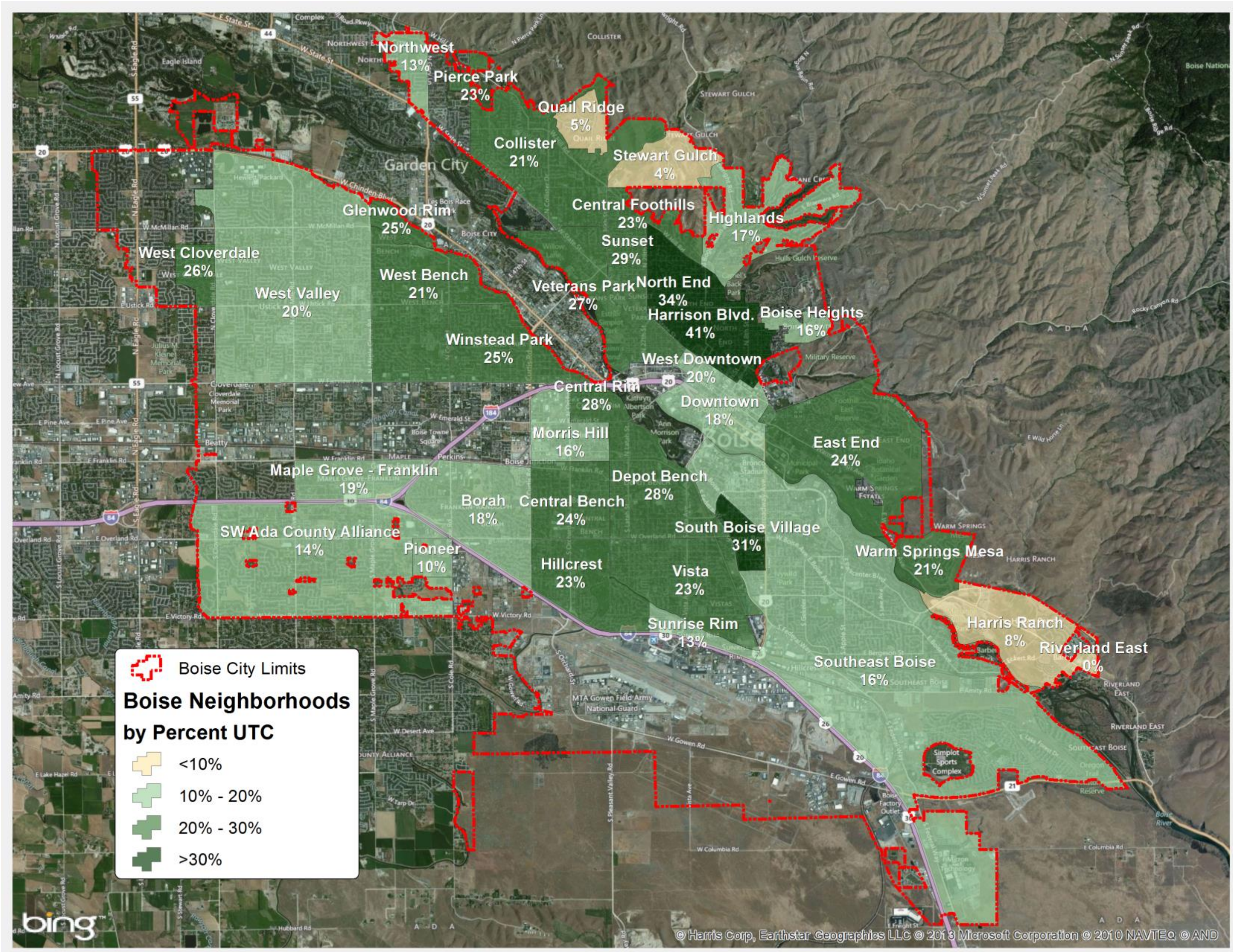


Figure 9. Boise neighborhoods symbolized by percent tree cover. Neighborhoods in the northeast part of town near the Boise River generally have the highest tree canopy cover while more recently developed parts of the city in the south and west have less.

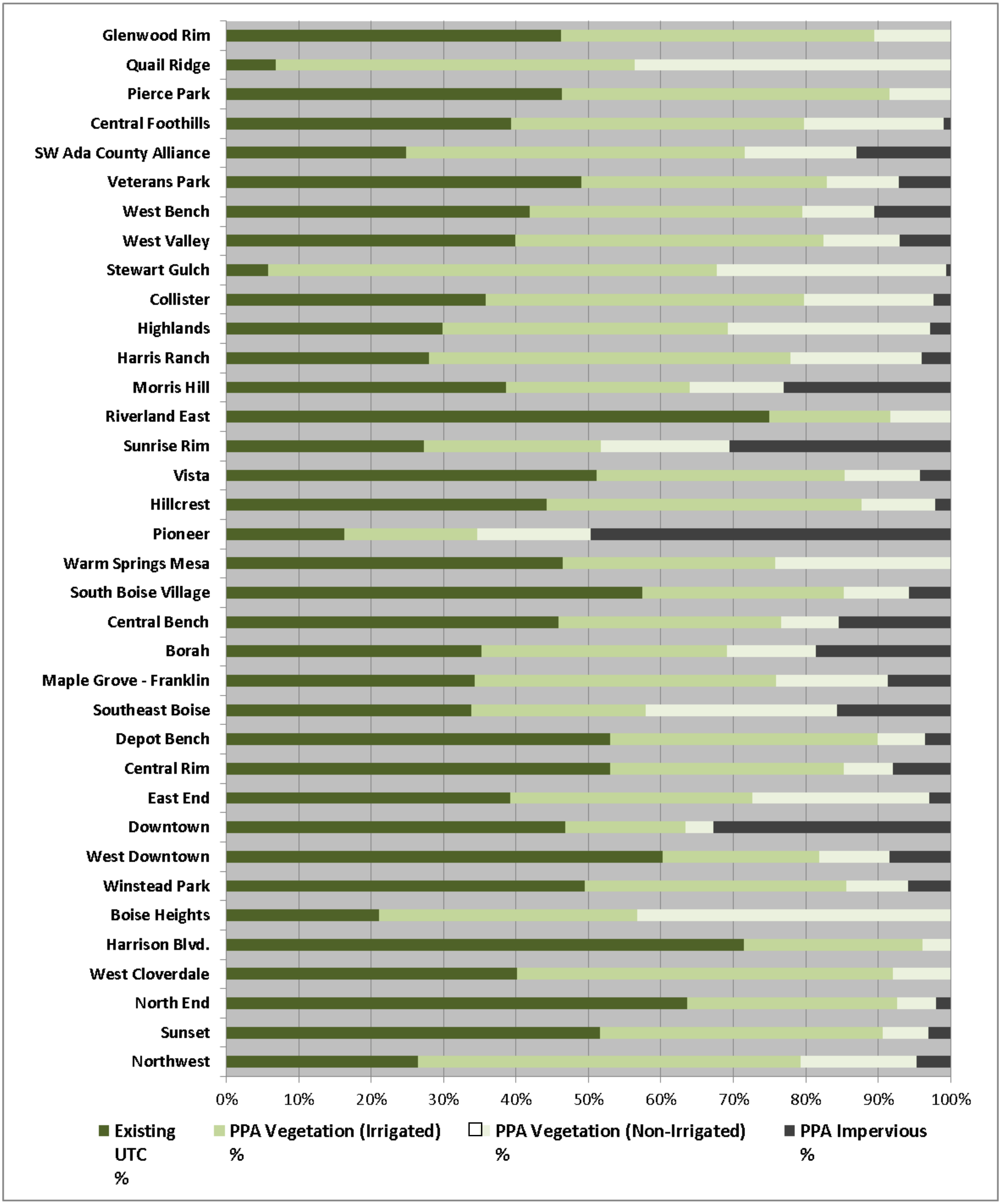


Figure 10. Comparison of UTC types for Boise Neighborhood Associations.

UTC Results for Census Blocks

Every ten years, the U.S. Census Bureau provides population estimates, socioeconomic and demographic data for the United States, summarized by various geographic scales. Census blocks are the smallest division and are the base scale for the Modeling Tools for Strategic Canopy Development Scenarios.

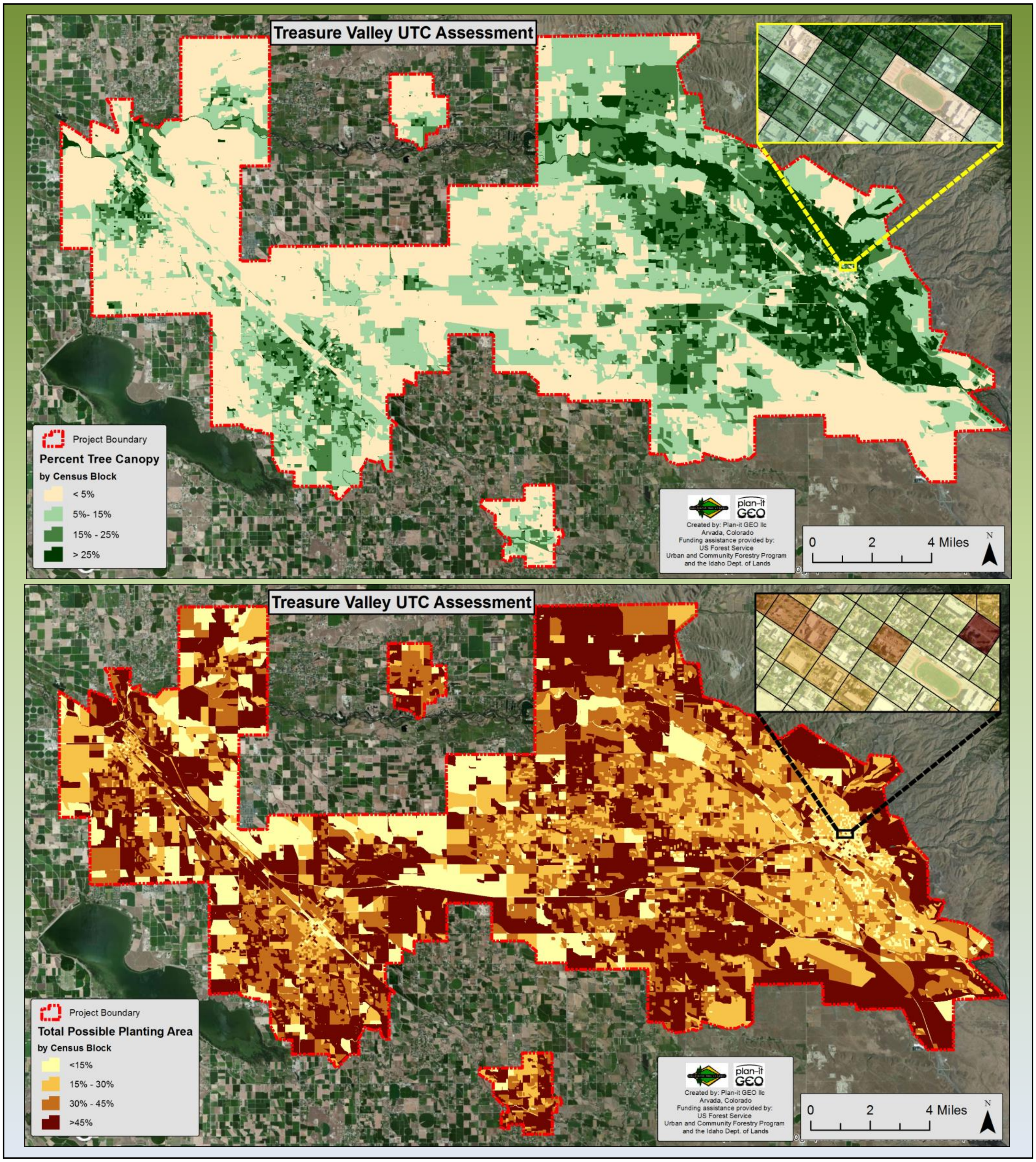


Figure 11. Existing UTC and total PPA for census blocks in the Treasure Valley study area.

UTC Results for Parcels

Parcels provide the finest detail of UTC assessment in this report. Once UTC and Possible Planting Areas are evaluated for larger areas such as neighborhoods or census blocks for broader planning and comparison purposes, the small size of parcels as an assessment boundary make them ideal for targeting individual landowners for outreach efforts or actions. As an example, Figure 12 below shows that possible planting space percentages at the parcel level can provide a great deal of information for urban tree canopy managers.

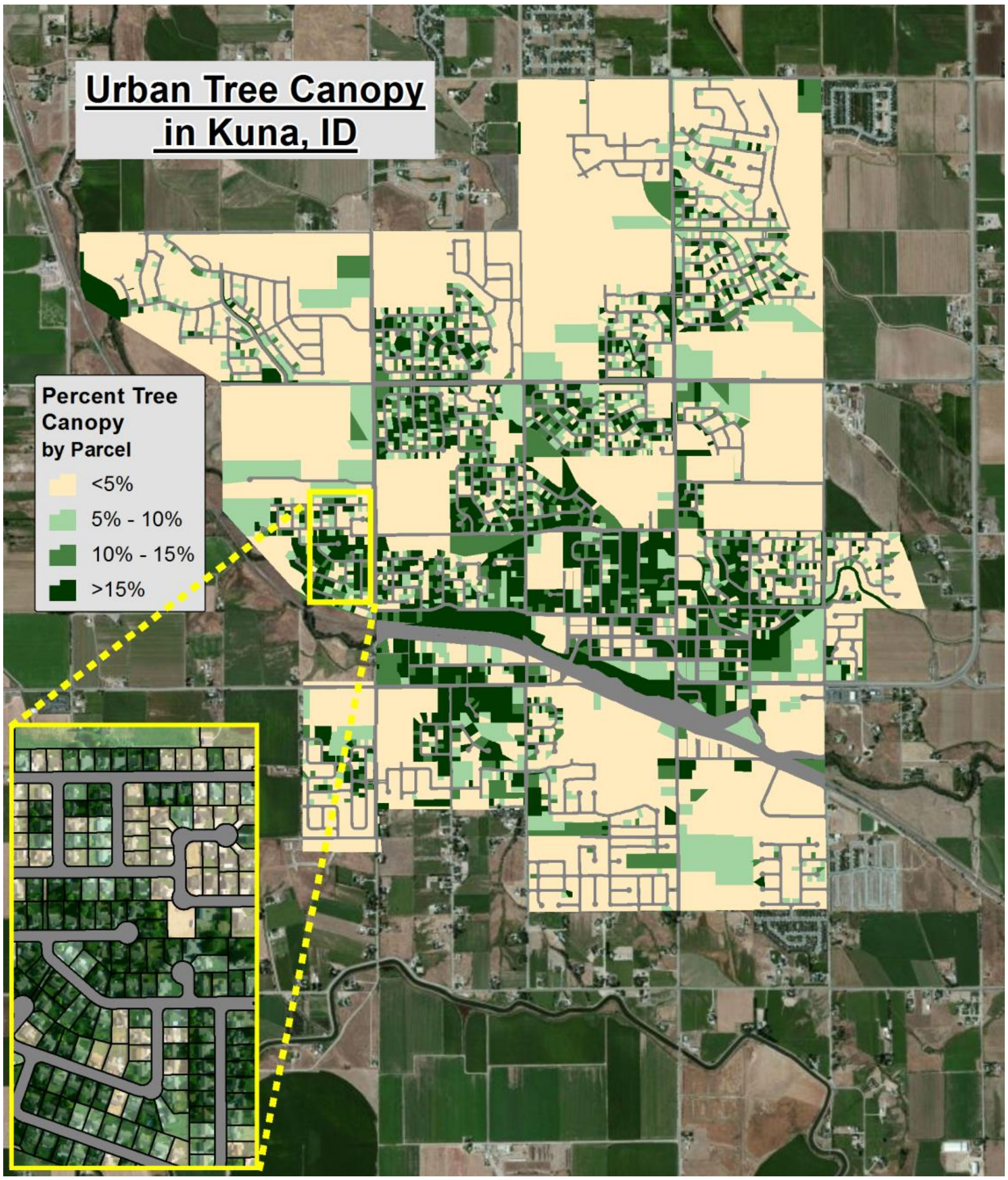
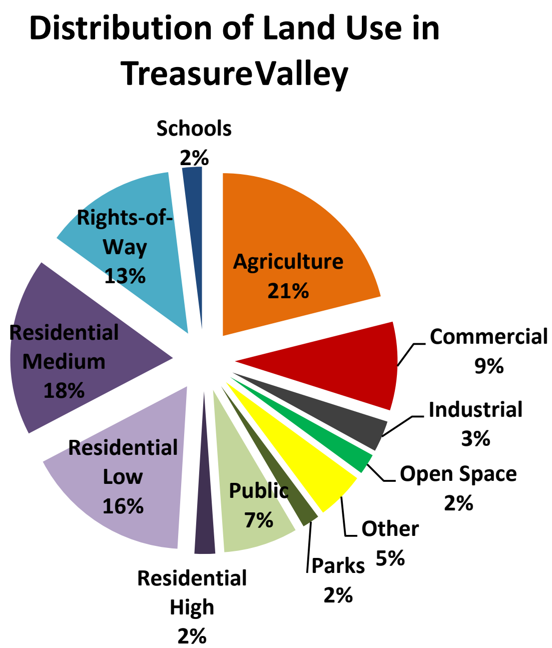
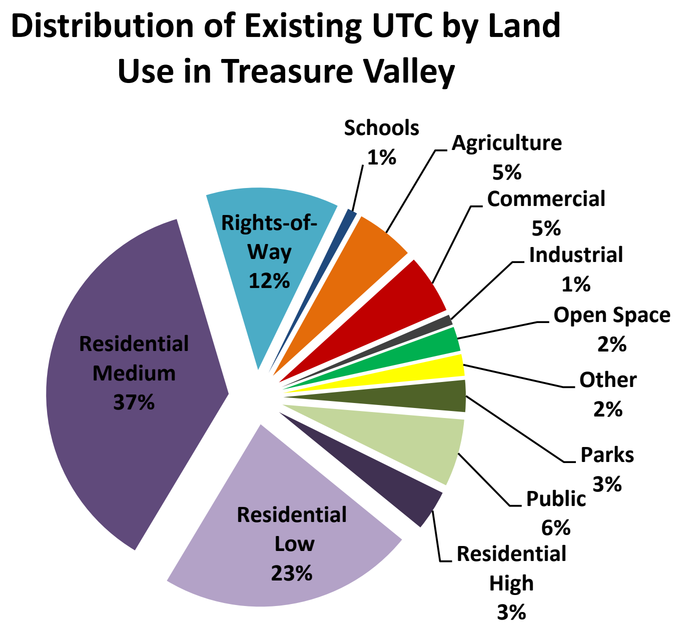


Figure 12. Parcels in Kuna symbolized by their percent existing tree canopy.

UTC Results for Land Use

Land use is a geographic measure that is commonly used by planners and managing officials to characterize the nature of land. In Treasure Valley land use was generalized into 12 categories.





Figures 13 a & b. Land use area percentages ***and distribution of tree canopy by land uses for the project AOI.***

Urban trees enhance the character and value in Treasure Valley's residential neighborhoods

UTC Results for Street Rights-of-Way

For this study, public rights-of-way (ROW) were considered to be municipal areas not assigned to a tax assessment parcel. ROW is comprised largely of streets but may also include stream corridors and utility easements. Cities have the most direct influence on urban tree canopy in street ROW, which equals 13% of all land in the Treasure Valley study area.

Existing canopy cover in Treasure Valley's ROW averages 9% with another 13% available for planting. For comparison, ROW makes up 17% of Boise with average tree cover at 12%, and 9% available space for planting. Canopy within Garden City's ROW was the highest at 18%.

GIS analysis of land cover data identified existing canopy cover and planting availability at the block-level for each city. Maps such as the one below (Figure 14) illustrate tools for targeting street tree planting and management activities.

- ✓ ***Street trees create vibrant communities by enhancing quality of life, increasing property values, and improving retail. A 2007 study valued Boise's street tree benefits at $1.2 million ($43/tree) annually.***

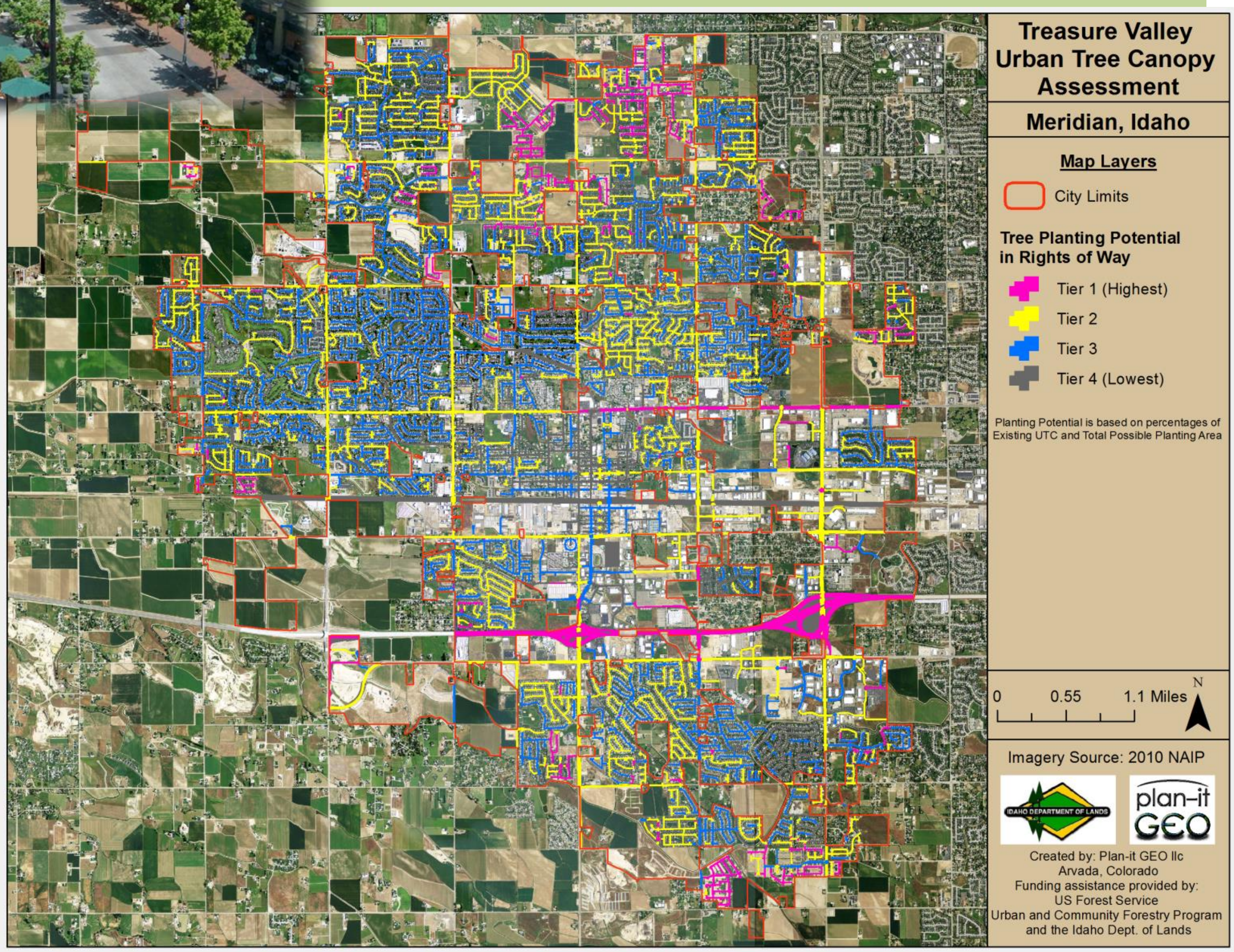


Figure 14. Planting potential in street rights-of-way. GIS queries were used to rank streets by UTC %.

Ecosystem Services Analysis Results

Using i-Eco analysis results for the entire study area, Plan-it Geo calculated ecosystem service values for each city based on current UTC, and future scenarios projecting a 5% increase in UTC across all cities. The i-Eco results are based on an estimated 2.4 million trees and a total of 119 square miles of leaf area reported across the Treasure Valley study area. A summary table of individual tree values for each ecosystem service averaged across the 12 selected species describes how these values increase with age and size (see *Appendix B* for more information on per-tree ecosystem service values). The remainder of this section provides per-tree results, then results for the study area and each city summarized by each assessed ecosystem service type. Managers and planners can examine all results or target a specific ecosystem service to learn more about how trees provide that specific service. The i-Eco report created from within the i-Tree software is available in Appendix E.

Per-Tree Ecosystem Service Results

Per tree ecosystem services illustrate the unit and dollar value inputs for the CommunityViz scenario planning tools (Table 5). The table shows average annual ecosystem service values for a single tree at five-year age intervals. These values are useful for managers, planners, and citizens in the Treasure Valley as a reference of the benefits trees provide, and to understand how the CommunityViz tools calculate ecosystem benefits.

Table 5. Annual ecosystem services values—in resource units and dollars—used in potential planting locations for the CommunityViz planning tools by five-year increments of tree age out to age 50

Tree Age	Storm Water (ga)	Storm Water ($)	Ozone (lbs)	Ozone ($)	PM 10 (lbs)	PM 10 ($)	PM 2.5 (lbs)	PM 2.5 ($)	AQ Total (lbs)	AQ Total ($)	Avg. Energy ($)	Avg. Energy (kWh)	Avg. Cooling ($)	Avg. Heating ($)	Total Savings ($)
5	10	0.09	0.05	0.07	0.04	0.34	0.00	0.23	0.10	0.64	0.00	0	0.00	0.00	0.73
10	76	0.67	0.38	0.52	0.32	2.4	0.01	1.6	0.78	4.6	0.00	0	0.00	0.00	5.3
15	240	2.1	1.2	1.6	1.0	8.2	0.05	5.6	2.5	15.5	22.2	286	20.3	1.9	39.8
20	507	4.5	2.5	3.4	2.2	17.9	0.11	12.3	5.2	33.7	71.7	978	70.3	1.3	109.8
25	950	8.4	4.6	6.3	4.1	33.2	0.21	22.8	9.8	62.6	130.6	1,961	142.5	-11.9	201.6
30	1,502	13.4	7.3	10.0	6.4	51.7	0.32	35.4	15.4	97.6	235.4	3,560	259.6	-24.2	346.4
35	2,231	19.8	10.8	14.8	9.4	77.0	2.8	53.1	25.0	145.6	343.1	5,245	383.6	-40.5	508.6
40	3,202	28.5	15.5	21.2	13.5	111.9	3.0	77.7	34.9	211.9	463.5	7,080	518.5	-55.0	703.9
45	4,172	37.1	20.2	27.7	17.6	146.8	3.3	102.3	44.7	278.2	583.8	8,915	653.3	-69.5	899.1
50	5,143	45.7	24.9	34.1	21.6	181.7	3.5	127.0	54.6	344.5	704.2	10,750	788.1	-84.0	1,094.4

Air Quality Results

Air Quality Results in the Treasure Valley Study Area

Trees remove a total of 581 tons of total air pollutants (270 tons of O3, 245 tons of PM10, and 15 tons of PM2.5) annually for an estimated $7.5 million in savings. See Appendix C for a detailed description of how trees work to promote better air quality in the Treasure Valley.

Air Quality Results by City

Table 6 shows the amount of six major air pollutants removed by trees in each city assessed in this analysis. Values are in total pounds removed annually based on current UTC. The "Total" column sums the values over all six pollutants. The "Future Total" column illustrates expected removals given a 5% increase in UTC based on future scenarios and the "Change" column explicitly illustrates the scenario gain.

Table 6. Air quality benefits of trees by city for current UTC and future scenario increase of 5% UTC

Category→	Air Pollution Removal								
Benefit→	CO	O_3	NO_2	PM <10µ	SO_2	PM <2.5µ	**Total**	**Future Total**	**Change**
Units→	lbs/yr							(5% UTC gain)	
Boise	14,097	240,129	26,645	223,215	477	11,482	516,045	541,847	25,802
Caldwell	1,450	24,701	2,741	22,961	49	1,181	53,083	55,737	2,654
Eagle	2,806	47,804	5,304	44,437	95	2,286	102,732	107,869	5,137
Garden City	1,032	17,575	1,950	16,337	35	840	37,769	39,658	1,888
Kuna	310	5,281	586	4,909	10	253	11,350	11,917	567
Meridian	2,219	37,790	4,193	35,128	75	1,807	81,211	85,272	4,061
Middleton	268	4,562	506	4,241	9	218	9,804	10,295	490
Nampa	2,841	48,401	5,371	44,992	96	2,314	104,016	109,217	5,201
Star	217	3,704	411	3,443	7	177	7,961	8,359	398
Unincorporated	7,197	121,916	13,483	113,961	244	5,862	262,663	275,796	13,133
Treasure Valley	**32,438**	**551,864**	**61,190**	**513,624**	**1,098**	**26,420**	**1,186,634**	**1,245,966**	**59,332**

Energy Use Results

Energy Use Results in Treasure Valley study area

Trees increase net energy costs annually by an estimated $213,000 in the region. By shading buildings, trees save $936,000 in cooling costs. However, by blocking winter sun—especially smaller trees on the south sides of homes, $1.15 million is spent for additional heating across the Treasure Valley study area. Energy benefits are a function of tree species, location relative to buildings, and size. More than half of the trees in the Treasure Valley are less than 6" in diameter and, as these grow taller, overall net energy benefits will increase. I-Tree analysis demonstrates that trees located on the west side of buildings provide the greatest positive energy benefits. See the Energy Impacts graphic (Figure 15) on the next page for more information on the effects of tree placement on energy savings (note the example uses i-Tree Design, a free web-based software for estimating tree benefits).

Energy Use Results by City

Table seven shows energy savings—in resource units and dollars—based on current UTC (Current Benefits) and with a five percent UTC increase (Future Benefits). City results are tied directly to the summary values for the entire study area and, since these values are negative, each of the cities shows negative energy use savings as well.

Table 7. Energy use values due to trees by city and for the Treasure Valley study area for current UTC and a future scenario increase of 5% UTC.

Energy Values												
	Current Net Benefits				Future Net Benefits				Change in Net Benefits			
Cities	BTUs Saved	Mwh Saved	Carbon Emissions Avoided	Energy Savings	BTUs Saved	Mwh Saved	Carbon Emissions Avoided	Energy Savings	BTUs Saved	Mwh Saved	Carbon Emissions Avoided	Energy Savings
	BTU/yr	Mwh/yr	lbs/yr	$/yr	BTU/yr	Mwh/yr	lbs/yr	$/yr	BTU/yr	Mwh/yr	lbs/yr	$/yr
Boise	-42.1 K	5,059	-1.25 M	-$137.1 K	-44.2 K	5,312	-1.31 M	-144.0 K	-2,104	253	-62.3 K	-$6,856
Caldwell	-4.3 K	520	-128.1 K	-$14.1 K	-4.5 K	546	-134.6 K	-14.8 K	-216	26	-6.4 K	-$705
Eagle	-8.4 K	1,007	-248.1 K	-$27.3 K	-8.8 K	1,057	-260.5 K	-28.7 K	-419	50	-12.4 K	-$1,365
Garden City	-3.1 K	370	-91.2 K	-$10.0 K	-3.2 K	389	-95.7 K	-10.5 K	-154	19	-4.6 K	-$502
Kuna	-.9 K	111	-27.4 K	-$3.0 K	-1.0 K	117	-28.7 K	-3.2 K	-46	6	-1.4 K	-$151
Meridian	-6.6 K	796	-196.1 K	-$21.6 K	-7.0 K	836	-206.0 K	-22.7 K	-331	40	-9.8 K	-$1,079
Middleton	-.8 K	96	-23.7 K	-$2.6 K	-.8 K	101	-24.9 K	-2.7 K	-40	5	-1.2 K	-$130
Nampa	-8.5 K	1,020	-251.2 K	-$27.6 K	-8.9 K	1,071	-263.8 K	-29.0 K	-424	51	-12.6 K	-$1,382
Star	-.6 K	78	-19.1 K	-$2.1 K	-.7 K	82	-20.1 K	-2.2 K	-32	4	-1.0 K	-$105
Unincorp.	-21.5 K	2,584	-636.7 K	-$70.0 K	-22.6 K	2,713	-668.6 K	-73.6 K	-1,075	129	-31.8 K	-$3,502
TV AOI	**-96.8 K**	**11.6 K**	**-2.89 M**	**-$315.5 K**	**-101.7 K**	**12.2 K**	**- 3.01 M**	**-331.3 K**	**-4.8 K**	**.6 K**	**-143.4 K**	**-15.8 K**

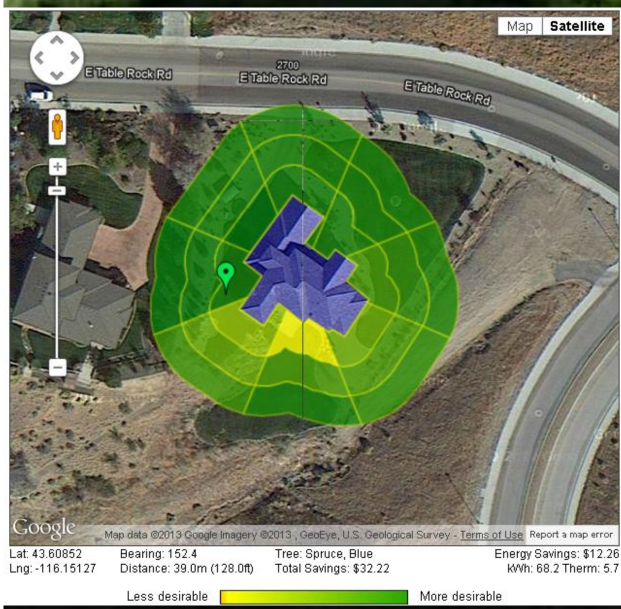
K = Thousand, M = Million

i-Tree Design Results

i-Tree Design was utilized to measure the impact of tree type (i.e. conifer vs. deciduous), tree size and location on the provision of benefits related directly to energy use.

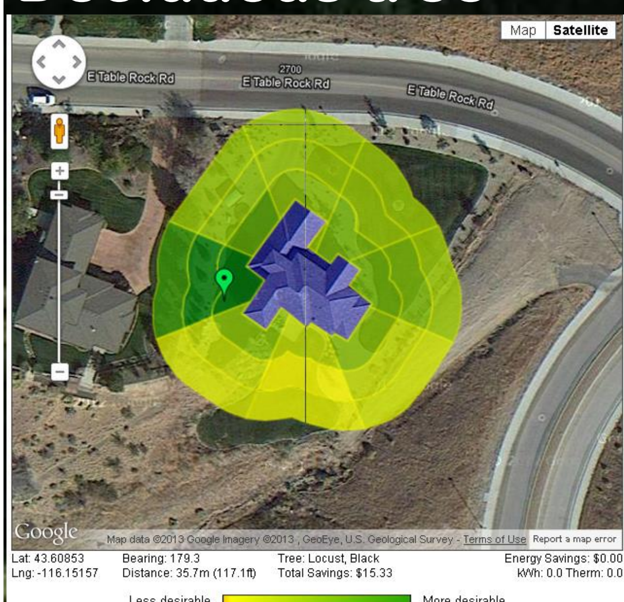
Energy Impacts

Conifer tree



Heating Cost Impacts		Cooling Cost Impacts	
N	$13.40	N	$5.06
S	-$8.86	S	$8.31
E	$2.96	E	$15.59
W	$3.61	W	$24.16

Deciduous tree



Heating Cost Impacts		Cooling Cost Impacts	
N	$2.61	N	$6.72
S	-$7.49	S	$10.01
E	-$5.97	E	$17.00
W	-$4.10	W	$24.93

* Dollar values are annual averages based on a 25-year old tree of medium height planted 10-meters (~30-feet) from 4 sides of a modern residential home.

Figure 15. i-Tree Design results illustrate how tree type and position can impact energy use values.

Stormwater Mitigation Results

Stormwater Results in the Treasure Valley Study Area

Trees mitigate approximately 125 million gallons of runoff annually across the Treasure Valley study area with an estimated value of $1.12 million in reduced stormwater infrastructure costs.

Stormwater Mitigation Results by City

Table 8 reports the unit and dollar values for stormwater mitigation for each city based on current tree canopy and the future scenario of a 5% increase in tree canopy.

Table 8. Stormwater mitigation values from tree canopy by City and for the Treasure Valley.

Stormwater Mitigation						
Cities	Current (Gals/yr)	Benefits (Dollars/yr)	Future (Gals/yr)	Benefits (Dollars/yr)	Change (Gals/yr)	(Dollars/yr)
Boise	54.32 M	$485.4 K	57.04 M	$509.7 K	2.72 M	$24.3 K
Caldwell	5.58 M	$49.9 K	5.86 M	$52.4 K	279.2 K	$2.5 K
Eagle	10.81 M	$96.6 K	11.35 M	$101.4 K	540.6 K	$4.8 K
Garden City	3.97 M	$35.5 K	4.17 M	$37.3 K	198.7 K	$1.8 K
Kuna	1.19 M	$10.7 K	1.25 M	$11.2 K	59.6 K	$.5 K
Meridian	8.55 M	$76.4 K	8.98 M	$80.2 K	427.4 K	$3.8 K
Middleton	1.03 M	$9.2 K	1.09 M	$9.7 K	51.7 K	.5 K
Nampa	10.95 M	$97.8 K	11.50 M	$102.7 K	547.5 K	$4.9 K
Star	.84 M	$7.5 K	.88 M	$7.8 K	42.8 K	$.4 K
Unincorporated	27.75 M	$248.0 K	29.14 M	$260.4 K	1.39 M	$12.4 K
Treasure Valley	**125.00 M**	**$1.12 M**	**131.25 M**	**$1.17 M**	**6.25 M**	**$55.9 K**

K = Thousand, M = Million

Carbon Sequestration and Storage Results

Carbon Benefits for the Treasure Valley Study Area

Total storage is 820 million pounds (410,000 tons) worth $29 million. Trees sequester an additional 31.0 million pounds (15,500 tons) of carbon valued at $1.1 million. See Tables 9-10 below. Note that carbon *storage* is what is currently stored "in the tree bank," and annual carbon *sequestration* is the annual "deposit," or additional carbon added, with tree growth.

Carbon Benefits by City

Tables 9 and 10 report the pounds and dollar values for carbon sequestration and carbon storage (respectively) by city based on current tree canopy and the future scenario of a 5% increase in tree canopy.

Table 9. Carbon storage values by city and the Treasure Valley study area

Carbon Storage						
Cities	Current Benefits		Future Benefits		Change	
	(lbs)	(Dollars)	(lbs)	(Dollars)	(lbs)	(Dollars)
Boise	356.34 M	$12.69 M	374.16 M	$13.32 M	17.82 M	$634.5 K
Caldwell	36.64 M	$1.30 M	38.47 M	$1.37 M	1.83 M	$65.2 K
Eagle	70.93 M	$2.53 M	74.48 M	$2.65 M	3.55 M	$126.3 K
Garden City	26.07 M	$.93 M	27.37 M	$.97 M	1.30 M	$46.4 K
Kuna	7.83 M	$.28 M	8.22 M	$.29 M	.39 M	$13.9 K
Meridian	56.08 M	$1.99 M	58.88 M	$2.10 M	2.80 M	$99.8 K
Middleton	6.78 M	$.24 M	7.12 M	$.25 M	.34 M	$12.1 K
Nampa	71.83 M	$2.56 M	75.42 M	$2.69 M	3.59 M	$127.9 K
Star	5.48 M	$.20 M	5.76 M	$.20 M	.27 M	$9.8 K
Unincorporated	182.03 M	$6.48 M	191.14 M	$6.81 M	9.10 M	$324.1 K
Treasure Valley	**820.00 M**	**$29.20 M**	**861.00 M**	**$30.66 M**	**41.00 M**	**$1.46M**

Table 10. Annual carbon sequestration values by city and the Treasure Valley study area

Carbon Sequestration						
Cities	Current Benefits		Future Benefits		Change	
	(lbs/yr)	(Dollars/yr)	(lbs/yr)	(Dollars/yr)	(lbs/yr)	(Dollars/yr)
Boise	13.47 M	$478.0 K	14.15 M	$501.9 K	673.6 K	$23.9 K
Caldwell	1.39 M	$49.1 K	1.45 M	$51.6 K	69.3 K	$2.5 K
Eagle	2.68 M	$95.1 K	2.82 M	$99.9 K	134.1 K	$4.8 K
Garden City	.98 M	$35.0 K	1.03 M	$36.7 K	49.3 K	$1.7 K
Kuna	.30 M	$10.5 K	.31 M	$11.0 K	14.8 K	$.53 K
Meridian	2.12 M	$75.2 K	2.23 M	$79.0 K	106.0 K	$3.8 K
Middleton	.26 M	$9.1 K	.27 M	$9.5 K	12.8 K	$.46 K
Nampa	2.72 M	$96.4 K	2.85 M	$101.2 K	135.8 K	$4.8 K
Star	.21 M	$7.4 K	.22 M	$7.7 K	10.4 K	$.37 K
Unincorporated	6.88 M	$ 244.2 K	7.23 M	$256.4 K	344.1 K	$12.2 K
Treasure Valley	**31.00 M**	**$1.10 M**	**32.55 M**	**$1.16 M**	**1.55 M**	**$55.0 K**

K = Thousand, M = Million

Potential Planting Locations Results

Available planting locations are presented by criteria (attributes) to allow users to prioritize sites. Table 11 at right shows there are roughly 62,000 planting sites in areas that could benefit air quality the most (major road corridors and parking lots). Site types are not mutually exclusive; a site can meet multiple criteria.

The sites provide a planning tool to cities for targeting tree plantings. Kuna, for instance, has the highest density of planting sites.

Attribute Type	Planting Sites
Energy	110,692
Air Quality	60,737
Street Tree	15,120
Right-of-Way	55,079
Schools	28,272
Parks	33,526
Public Transit	479
Owned (not rented)	892,059
Riparian	182,880
Developed	508,516

Table 11. Number of planting sites meeting specific priority attributes (out of 1.84M total)

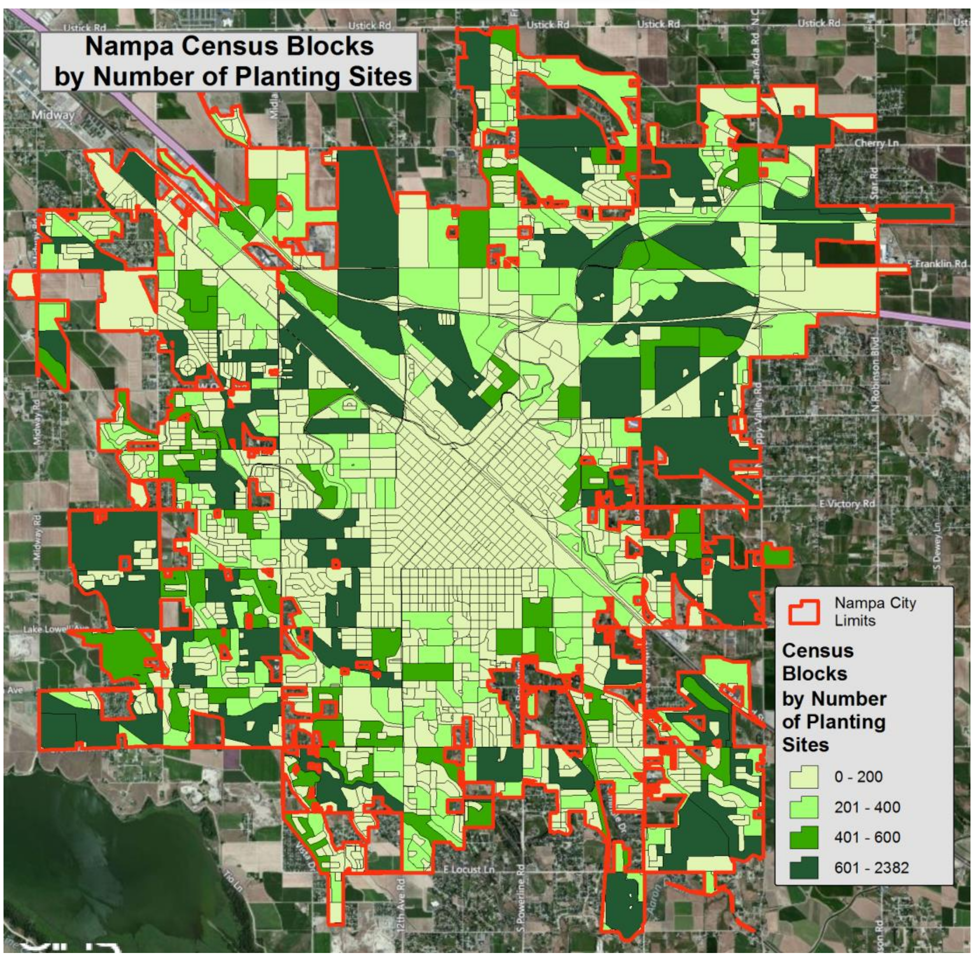


Figure 16. Census blocks in Nampa symbolized by number of potential planting sites. Dark green areas have the most planting sites.

City	Number of Planting Sites	Sites per Acre
Boise	129,928	3
Caldwell	44,579	4
Eagle	30,484	3
Garden City	8,033	3
Kuna	13,887	5
Meridian	70,315	4
Middleton	7,324	3
Nampa	76,395	4
Star	7,073	4

Table 12. Number and density of planting sites by City

Modeling Tools for Strategic Canopy Development Scenarios

Using the CommunityViz software and tools described within *Project Fundamentals* on page 19, three example scenarios below demonstrate the use of the data and software to identify priority tree planting areas, and forecast future tree canopy and associated ecosystem benefits. To illustrate the regional and site-specific scale at which the tools can be used, the example scenarios focus on:

- ***Regional*** **Air Quality**
- ***Regional*** **Energy Conservation**
- ***Site-Level*** **Stormwater Management**

At a high-level, the tools and steps used in the two regional-scale scenarios are as follows:

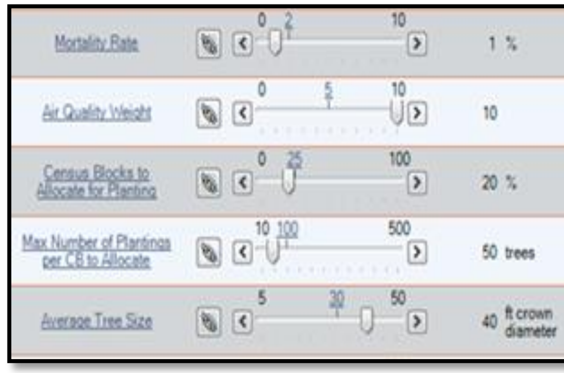
- Census block polygons now include information from the assessment such as UTC and Potential Planting Area (PPA) metrics (area and percent) as well as custom fields and attributes, including proximity to highways, parking lots, riparian corridors, residential homes, and specific land use types, to name a few.
- User controls, aka "slider bars" (CommunityViz (CV) Assumptions), can be adjusted to change variables such as what areas have the greatest potential to maximize tree benefits, how many trees are planted in a model, the size of those trees, how many are near homes, and to what future year benefits should be projected.
- Once these parameters and values have been selected, the model runs formulas and updates charts showing summary totals of the new trees planted, future canopy cover, and expected cumulative benefits to the future year selected.

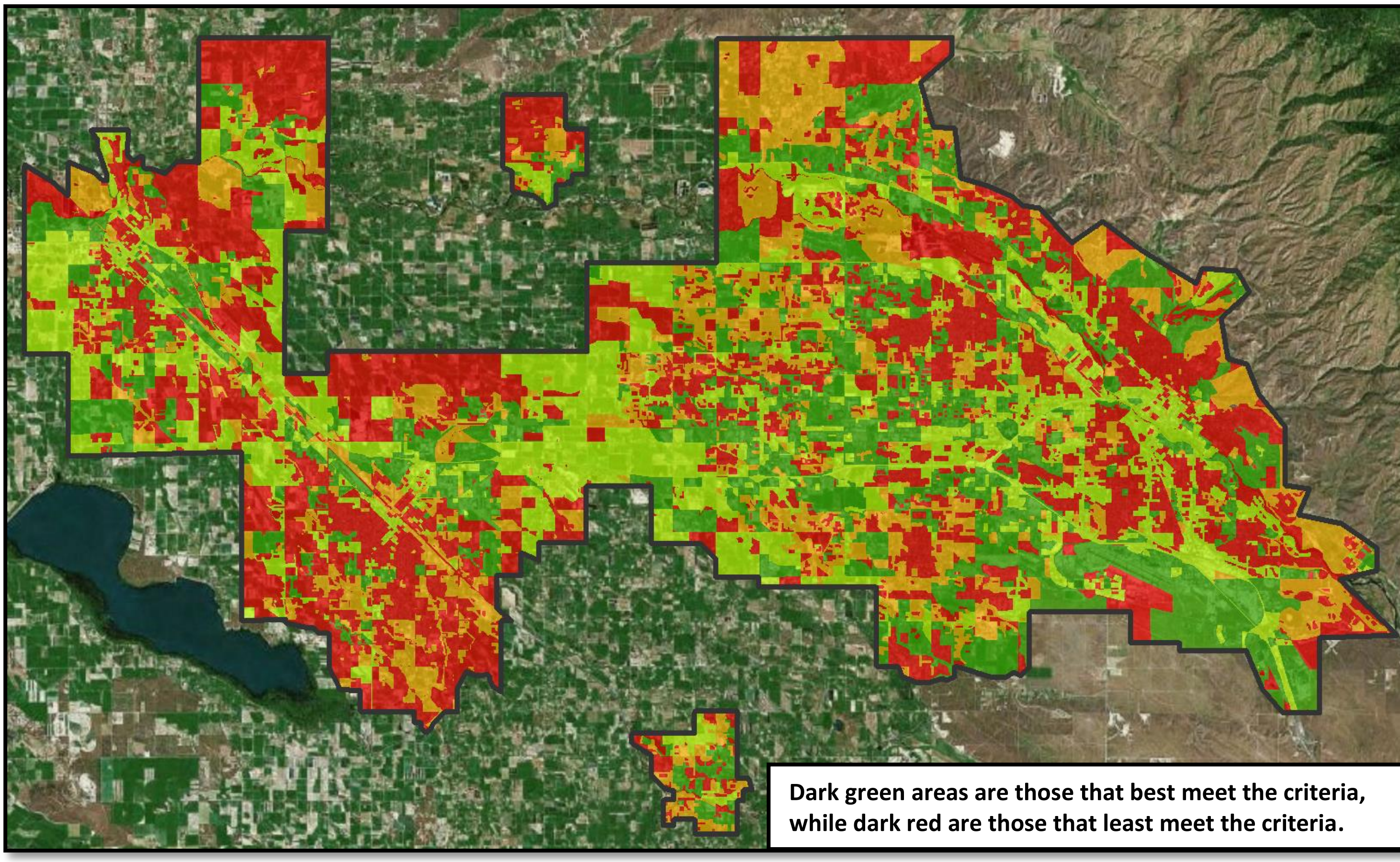
At a high-level, the tools and steps used in the site-level scenario are as follows:

- A demonstration of the site-specific application of the CV tools, in this example for stormwater management around parking lots on a church property
- Trees types available in the CV tools are planted as a buffer around the parking lot on that property. Cumulative costs are calculated based on user entered average costs per tree for site preparation, tree purchase, planting, and annual maintenance.
- Several types of ecosystem benefit values are summarized in CV charts for the trees shown based on cumulative, "lifetime" accrual of benefits. Long-term tree costs are weighed against forecasted benefits for the species values based on i-Tree Eco inventory and analysis results.

Air Quality Scenario | Assumptions Used:

- **Priority areas for planting:** near highways, major streets, parking lots, and areas of low UTC and high planting space
- Plant trees in 20% of census blocks starting with the highest suitability score (those which best meet the conditions given), with a maximum of 50 trees planted per census block
- 50-year grow-out, 1% mortality, and a 40' avg. tree crown





Dark green areas are those that best meet the criteria, while dark red are those that least meet the criteria.

Tree and Canopy Outcomes

- No. of Trees Planted and Grown Out: **47,499**
- Updated Regional UTC (*not including growth of existing UTC*): **13.4%**
- With up to 150 trees per CB, new UTC would jump to **13.8% (21,150 additional trees).**

Cumulative Eco Benefits

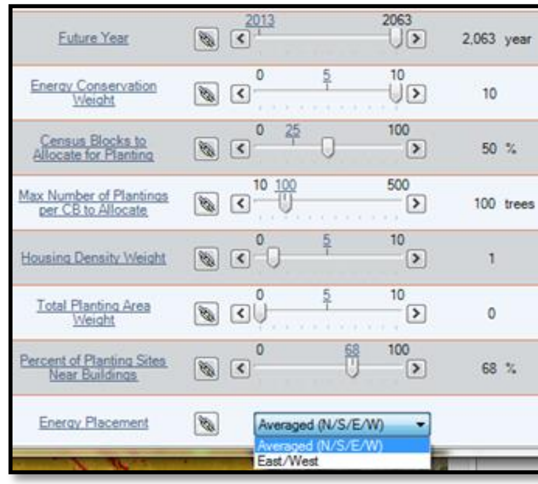
- Air Pollutants Removed: 259.6 tons valued at **$3.2M**
- PM 10 Removed: 102.6 tons valued at **$1.7M**
- PM 2.5 Removed: 17.9 tons valued at **$1.2M**
- Ozone Removed: 117.6 tons valued at **$321.7K**

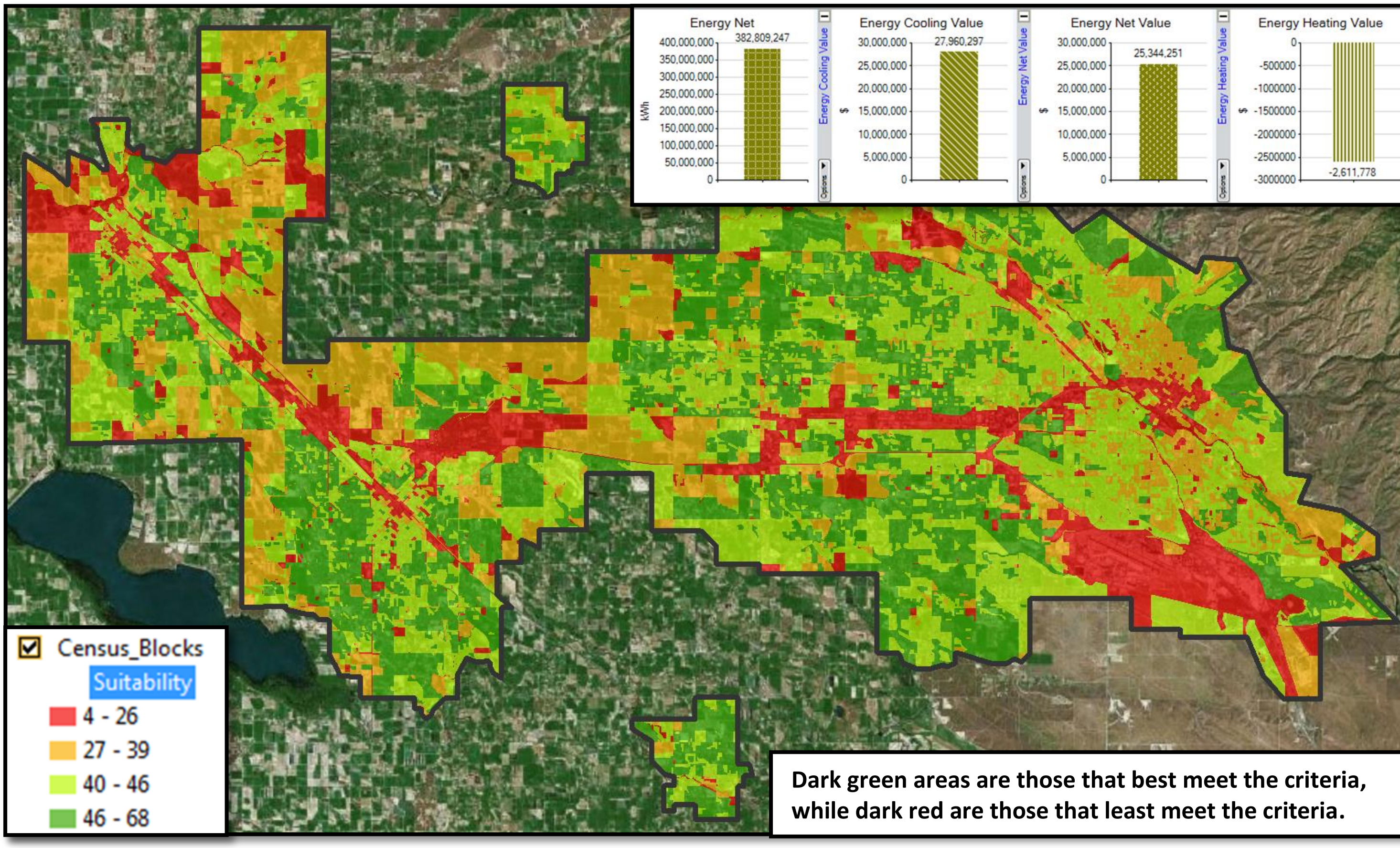
Other Benefits

- Public health improvement such as reduced asthma occurrences
- Street beautification
- Noise reduction
- Improved retail shopping along business arterials

Energy Efficiency Scenario | Assumptions Used:

- **Priority areas for planting:** Near residential buildings with low UTC and high planting space near the building
- Plant trees in 50% of census blocks starting with the highest suitability score, with a max of 100 trees planted per census block
- 50-year grow-out, 1% mortality, and a 40' avg. tree crown at maturity





Dark green areas are those that best meet the criteria, while dark red are those that least meet the criteria.

Tree and Canopy Outcomes

- No. of Trees Planted and Grown Out: **155,988**
- Future Regional UTC (*includes a growth rate of 1.5% for existing UTC*): **15.3%**

Note that Eco Benefits reflect newly planted trees over time, not all at once, and do not include existing tree benefits.

Cumulative Eco Benefits

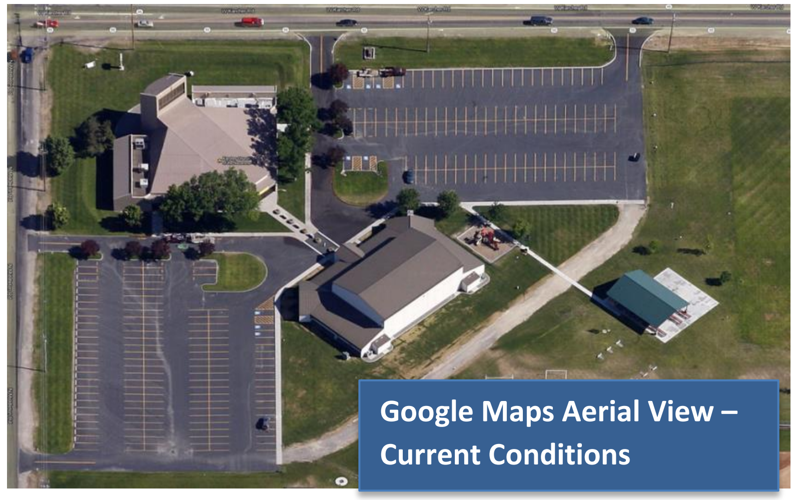
- Net energy conserved: 206,**518 MHW**
- Summer cooling: **$15.1M**
- Winter heating: -$1.4M
- Net Value: **$13.7M**
- With trees on the East and West side of houses only, the net value would be **$18.4M**.

Other Benefits

- Quality of life from comfortable shaded neighborhoods
- Financial savings for residents
- Demand-side energy management for Idaho Power during peak loads

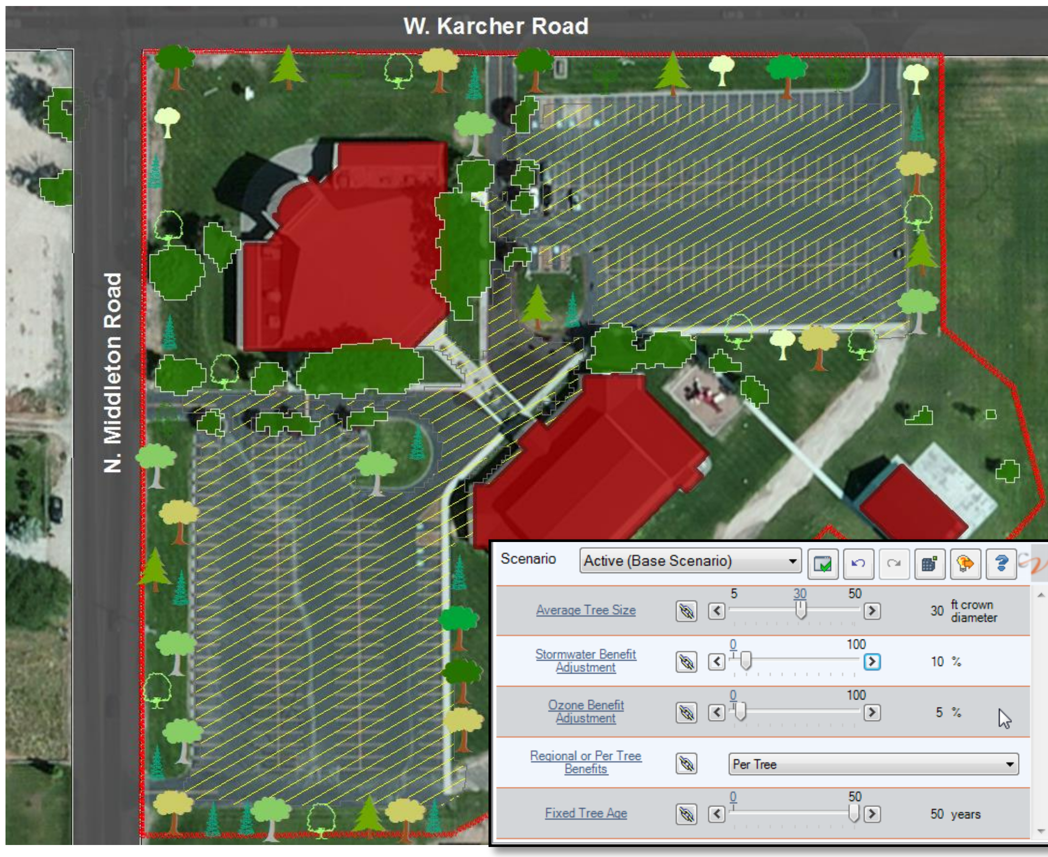
Stormwater Scenario | Assumptions:

- **Tree Purchase Price**: $49/tree
- **Labor for Tree Planting**: $10/tree
- **Site Improvement**: $5/tree
- **Maintenance Cost**: $8/tree/year
- **Grow-Out Age**: 50 years



Map Legend

- Tree Plantings
  - Tree Species or Genus
  - Ash
  - Birch
  - Elm
  - Honey Locust
  - Linden
  - Maple
  - Oak
  - Pear
  - Pine
  - Spruce
  - Sweetgum
  - Sycamore
- Planting Site Boundaries
- Nampa_Roads
- Nampa_Tree_Canopy
- Nampa_BuildingFootprints
- Nampa_ParkingLots



Summary and Outcomes

- Nampa, Idaho – **Karcher Church Tree Planting Design**
- No. of Trees Planted and Grown Out: **53**
- Time horizon: **50 years**
- Lifetime Costs: **$24,592**
- Lifetime Benefits: **$28,997**
- Cost/Benefit Ratio: **1.2**

Cumulative Eco Benefits

- Stormwater Runoff Mitigated: **425,416 gallons valued at $3,786**
- Air Pollutants Removed: **2.3 tons valued at $25,211**
- CO2 Sequestered: **76,679 lbs**
- Note: no energy $-savings due to non-residential setting

Other Benefits

- Reduced pollutants entering source waters (streams)
- Shade in areas with high impervious surface cover
- Reduced ozone formation
- Beautification that in turn improves retail shopping

UTC Goal Setting Results

The "75th Percentile Rule" (Poracsky and Lackner 2004) was developed by researchers at the University of Portland to provide a system for setting tree canopy goals that incorporate locally specific data.

The current 75th percentile target in the Treasure Valley using parcels is 28% tree canopy, and using census blocks is 22%. Of the 206,130 parcels in the TV study area, one-quarter—or 51,532 parcels—currently have 28% tree canopy or higher, while 154,598 are below this threshold (see Table 13, bottom row). Given the region is currently at 10% overall tree canopy, a conservative goal of 20% tree canopy is suggested as a reasonable and attainable target for the Treasure Valley and can be assessed in future studies.

UTC Goal Setting Principles:

- Goals should challenge a community but be attainable
- Goals should reflect local resources, conditions, and desires
- Goals should be flexible enough to reflect current conditions and be easily updated as urban forest conditions change
- Goals should be applicable at the management scale

Table 13. The 75th percentile applied by land use across the Treasure Valley study area.

Land Use Category	Current UTC Percent	75th Percentile UTC Percent	Additional Percent Required	Total Number of Parcels	Number of Parcels Above Goal	Number of Parcels Below Goal
Agriculture	2.4%	4.2%	1.8%	5,578	1,395	4,183
Commercial	5.9%	11.0%	5.1%	11,624	2,907	8,717
Industrial	2.9%	4.3%	1.4%	1,011	253	758
Open Space	10.3%	18.4%	8.1%	58	15	43
Other	4.0%	7.1%	3.1%	8,675	2,169	6,506
Parks	16.2%	25.0%	8.8%	294	74	220
Public	8.0%	39.2%	31.2%	10,064	2,517	7,547
Residential High	17.3%	22.3%	5.0%	15,632	3,909	11,723
Residential Low	13.6%	27.1%	13.5%	17,611	4,403	13,208
Residential Medium	20.5%	30.4%	9.9%	135,393	33,849	101,544
Schools	4.4%	8.4%	4.0%	190	48	142
All Parcels	9.8%	28.0%	18.2%	206,130	51,532	154,598

Calculating the 75th percentile by land use provides a direct link between canopy goals, land management decisions, and implementation planning. When considering the 75th percentile targets by land use, Table 13 identifies the current tree canopy percent, 75th percentile target, and the corresponding count of parcels above and below the 75th percentile. In most cases, target tree canopy percentages using this method are significantly higher than current tree canopy. This occurs when parcels (or census blocks) near the top 25% have significantly higher canopy cover percent than the average canopy cover of the lowest 75% of parcels. The size distribution of parcels, census blocks, or other features also has an impact on resulting goals.

The 75th percentile targets are fundamentally based on the concept that a healthy, sustainable urban forest will continually expand. This is often the goal of urban forest managers and is applicable in the Treasure Valley considering the historic scarcity of tree canopy in the region.

Applying a future year at which tree canopy targets are met can also adhere to the 75th percentile principles but is more feasible with either prior or future canopy data. In other words, future UTC assessment in the Treasure Valley will provide an idea of the trajectory of tree canopy change corresponding with the level of efforts that have been applied and resources available over the time between the assessments.

Figure 17. Example of the 75th percentile applied for residential parcels in the South Boise Village neighborhood association.

Using 75th Percentile Targets:

Parcels in the South Boise Village neighborhood are illustrated by citywide percentile goals. Green parcels have achieved the 75th percentile target for the City (at least 37.8% canopy cover). Remaining parcels can be targeted in plans aiming to increase canopy cover.

Treasure Valley Core Team Training Session – March 18, 2013 – Boise State University Campus

On March 18, 2013, the TV UTC Core Team Partners met for a full-day technical training session presented by Plan-It Geo and coordinated by IDL and The Keystone Concept. City forestry and GIS staff as well as representatives from Idaho Power, COMPASS, Ada County Highway District, the U.S. Forest Services, and private organizations from the TV region explored the GIS and other (Excel/PDF) products from the project. The afternoon focused on how to use the CommunityViz canopy scenario planning tools.

Partners were very excited about the tools and the partnership between GIS Staff and Forestry staff was a critical link. Together these teams will be able to maximize use of the tools.

A discussion at the conclusion of the training also indicated an interest and need to have quarterly meetings to continue the efforts of TV Canopy. This ongoing interaction will aid in sharing information, learning how to best use the tools from this project, scenarios various partners find most beneficial, and enhancing management and development of tree canopy in the Treasure Valley based on the data, tools and project information.

This report and supporting documentation in the Appendices provide a process for locating and navigating the tools available from this project.

A complete list of attendees and the full day training agenda can be found in Appendix D.

Dave Stephenson (IDL) and Lance Davisson (The Keystone Concept) summarize outcomes and get feedback from Core Team Partners at the March 18th training session

Recommendations for Implementation

This project mapped land cover over nine communities and adjacent lands within the Treasure Valley, identified 1.8 million possible planting locations with extensive attributes, integrated this data with i-Tree Eco benefit values and inventory information, and developed tools allowing managers to better understand the cost-benefits of urban trees for specific purposes, and model future values based on robust scenario modeling tools. Based on the results of this work, the following broad recommendations are provided on how to best use these data, tools, and information to implement urban tree canopy objectives in the Treasure Valley.

Land Cover Analysis

- ✓ Disseminate the GIS (vector/raster) land cover data layers broadly to diverse partners for use in other applications while the data is current
- ✓ Continue to work with diverse partners to integrate the land cover data and ecosystem services benefit values into decision-making and implementation planning
- ✓ Re-assess canopy cover in no less than 10-year intervals, and use LiDAR data if available aiming for 95% overall accuracy

UTC Assessment

- ✓ Use the assessment data to:
    - o Establish canopy goals by city and land uses through development of implementation plans in a collaborative, multidisciplinary process. Reassess canopy periodically to measure progress toward goals and effectiveness of education/outreach and tree-related management and policies.
    - o Foster public and private tree planting in priority areas within each community
    - o Determine if tree planting in new development is achieving desired outcomes
- ✓ In future studies use up-to-date cadastral data and consistent land use categories and assessment methods. For instance, tree canopy % for the region and per city was calculated based on land area, excluding water area.
- ✓ Host the UTC data layers in an online application focused on urban forest planning. Using the tool, work with Community Planning Association of SW Idaho (COMPASS), Boise State University, neighborhood associations, school boards, developers, environmental non-profits, and public health professionals to enable volunteerism and citizen science to advance urban tree canopy benefits.

Ecosystem Benefits Analysis

Air Quality (AQ)

- ✓ This study identified 122,000 potential tree planting locations along major road corridors. Idaho Department of Environmental Quality (DEQ), Ada County Highway District (ACHD), COMPASS, and public health officials can partner to target canopy increases in the corridors as an air pollution mitigation strategy.
- ✓ Parking lots cover roughly 5,700 acres (3%) of the TV region. With nearly 36,000 potential planting sites within 50-feet of parking lots, these same partners plus local businesses can, by planting trees, maximize tree benefits in these areas, reducing the urban heat island effect and ground-level ozone formation.
- ✓ Through use of the TV Canopy tools and GIS data, local AQ managers and modelers can investigate additional opportunities for strategic, site-specific strategies where tree planting can enhance local air quality impacts—potentially leading to recognition of these benefits in future air quality planning documents and mitigation strategies.

Energy

- ✓ Maximize the energy conservation benefits of urban trees by encouraging nurseries and neighborhood associations to educate residents on proper placement, specifically:
  - The east and in particular west side of homes for summer cooling benefit
  - Avoid planting conifer or deciduous trees on the south side of homes to reduce winter shading and an increase in heating costs
  - Plant trees on the north side of homes; conifer species in particular provide both winter and summer energy savings
  - Supporting data: Out of 330,000 potential planting sites near buildings, roughly 70,000 are on the west side of homes, indicating enormous potential in the region for tree canopy expansion for energy conservation.
- ✓ Consider residential tree planting incentive programs aimed at reducing peak energy consumption using the TV Canopy tools and GIS data to identify and target specific planting locations, such as the pilot project Idaho Power is developing with several TV Canopy Partners
- ✓ Encourage homeowners to utilize free online tools such as i-Tree Design to determine proper placement of trees around their homes for energy benefit

Stormwater

- ✓ Utilize geospatial and UTC data in watershed planning to prioritize potential planting locations for protecting water quality
- ✓ Encourage the use of trees in Green Infrastructure / Low Impact Development (GI/LID) stormwater mitigation strategies, where appropriate

- ✓ Develop a public/private incentive program to plant and maintain large trees in and around parking lots to reduce the urban heat island effect and flow of contaminated runoff into surface waters. The benefits of planting and maintaining 36,000 potential planting sites in parking lot buffers in the TV region can be modeled with the data and tools from this study and presented to officials as an important economic and environmental sustainability initiative.

Carbon

- ✓ Plant large tree species that thrive in the region's drier conditions and extreme seasons to increase survivability, longevity, and carbon storage
- ✓ Minimize the use of heavy carbon-emitting machinery in tree maintenance practices

Tools for Strategic Canopy Development Scenarios

- ✓ As new or better values from i-Tree software become available over time, update the Urban Forest Scenario Tools with new values for the 12 genera
- ✓ Utilize the tools at the regional-level to show elected officials and city managers the potential value of a robust, working urban forest, and at the site-level to track plantings and compare design alternatives of tree planting and maintenance
- ✓ Work with COMPASS—which is using CommunityViz software as part of their 2040 Communities in Motion plan—to foster better use of the tools with communities with fewer resources and staff expertise. Additionally, utilize the detailed user's guide and documentation on the CV tools provided by Plan-It Geo.
- ✓ Host the potential planting location points in a GIS web mapping application so that non-GIS users can easily query, display, and create maps of priority planting areas

Training and Core Team Partners

- ✓ Continue technical how-to trainings in person and via webinar (online meeting) with IDL, the Keystone Concept, and other local partners
- ✓ Continue developing partnerships and create early success stories using the data and CV tools to showcase at partner meetings
- ✓ Using project data, tools, and results develop targeted presentations for city leaders, planners, engineers, air and water quality managers, and others on the functional benefits of urban tree canopy in addressing critical regional issues.

Summary and Conclusions

Not historically a forested area, people moving into the Treasure Valley planted the majority of the 2.4 million trees that shade a tenth of the 250 square miles of developed lands included in this study. While Garden City and Boise average 20% and 16% canopy cover respectively, the Harrison Boulevard neighborhood in Boise has achieved a 41% canopy cover—an indication of what is feasible when trees are a priority to a community.

The Treasure Valley's urban forest is relatively young; half of all trees are 6" or less in diameter. Nonetheless, each year the existing tree canopy provides over $1 million in stormwater reduction benefits and $7 million in human health benefits due to cleaner air. In addition, 1 million potential planting locations exist near developed areas. Because planting and maintaining all of these sites is unrealistic, the geospatial data and scenario-planning tools developed through this project are designed to guide decisions on the best places to invest in tree planting to lower stormwater runoff, conserve energy, improve air quality and enhance human health within the Treasure Valley, and calculate the future value of these investments. As the existing trees grow larger and new trees planted, the ecosystem benefits provided by the urban forest will likewise continue to expand.

While GIS and ecosystem analysis of trees is an evolving science and continually improving, the Treasure Valley UTC Assessment combines the best available science on urban forest ecosystem services with geospatial canopy assessment data and state-of-the-art scenario-planning tools.

Numerous products and resources are now available to partners and the public. The following links provide some of these resources:

- The Treasure Valley Canopy website, administered by David Stephenson (IDL): www.TV.terrasummit.com.
- A recording of the training session is available through the following link: http://cobe-video.boisestate.edu/Mediasite/Play/005ebde68d5d4180b59678a2436fc9981d?catalog=7404c700-8920-4de9-8c8c-94bb8f1d0573.
- A number of the GIS products will also be available on the Inside Idaho website: www.insideidaho.org.
- Plan-It Geo maintains copies of the data and tools and are an additional resource for technical assistance (www.planitgeo.com | info@planitgeo.com).

Additional documentation and other supplemental information are provided in the Appendix.

References

The following are citations for references used in this report.

1) i-Tree Eco Study in the Treasure Valley. 2011.
2) USDA Forest Service Center for Urban Forest Research. *City of Boise Municipal Forest Resource Analysis*, http://www.fs.fed.us/psw/programs/uesd/uep/products/2/psw_cufr693_BOI_MFRA_web.pdf, Published June 2007, accessed May 2013.
3) USDA Forest Service Center for Urban Forest Research. *Interior West Community Tree Guide, http://www.fs.fed.us/psw/publications/documents/psw_gtr205/psw_gtr205.pdf.* Published December 2007, accessed May 2013.
4) Placeways (2013).CommunityViz software extension for Esri ArcGIS software.
5) American Forests. *Support Urban Forests Initiatives*, http://www.americanforests.org/what-we-do/what-we-do-urban-forests/, Published 2012, accessed September 12, 2012.
6) Maryland Department of Natural Resources, Forest Service Urban and Community Forestry. *Chesapeake Bay Tree Canopy Goals,* http://www.dnr.state.md.us/forests/programs/urban/urbantreecanopygoals.asp Accessed October 12, 2012.
7) Benefits of Trees and Urban Forests: A Research List

   http://www.actrees.org/files/Research/benefits_of_trees.pdf. Published August 2011, accessed January 9, 2013.
8) Porasky, J and M. Lackner. 2004. Urban Forest Canopy Cover in Portland, Oregon, 1972-2002: Final Report. Available online @: http://web.pdx.edu/~poracskj/Cart%20Center/psucc200404-047.pdf. Accessed 07 March 2013.

Glossary of Terms

The following terms and acronyms are used throughout this report. Terms within definitions shown in *italics* are defined within the glossary of terms.

Land Cover Terms & Acronyms

- **Land Cover Classes**: These describe the physical state of the ground surface when viewed from above. Land cover classes used in this assessment are: Tree Canopy (deciduous and conifer), Irrigated Vegetation, Non-irrigated Vegetation, Soil & Dry Vegetation, Building, Road, Parking Lot, Other Impervious and Water.
- **NAIP - National Agricultural Imagery Program:** A program through the U.S. Department of Agriculture – Farm Service Agency (USDA – FSA) since 2003. This program acquires and distributes "leaf-on" aerial imagery of the continental US. 1-meter 4-band NAIP imagery was used in this assessment as an input to *OBIA* for mapping *land cover classes*.
- **OBIA – Object Based Image Analysis**: A remote sensing technique used in this study for performing image classification based on more than individual pixel values; OBIA involves pattern recognition, textural analysis, and context in conjunction with spectral values.

Urban Tree Canopy Terms & Acronyms

- **AOI – Area of Interest**: The full geographic boundary for this assessment (see Study Area map in the Background section on pg. 3).
- **Assessment Boundaries**: *GIS* polygon features that break up the *AOI* into finer scales. These are used to provide *UTC analysis* data at different meaningful scales. Examples include city limits, census blocks, neighborhoods, and parcels. See Table 1 page 8.
- **Urban Tree Canopy Analysis**: Mapping and analysis that uses *GIS* software to determine the amount of each *UTC type* within an *assessment boundary.*
- **Tree Canopy Cover:** The percent of tree canopy occupying an area for any scale assessment boundary.
- **Urban Tree Canopy Types**: Groupings of *land cover classes*, based on the relationship between land cover and urban forestry analysis. See UTC Types on page 7.
    - **Existing Urban Tree Canopy (UTC)**: Areas covered by tree canopy when viewed from above (map view) including trees in private lands, trees along public streets, natural forest tracts in open spaces, and along streams.
    - **Possible Planting Area (PPA) Vegetation**: Any area of grass, shrubs, or open space vegetation where it is biophysically feasible to plant trees including yards, open fields (non-agricultural), open park lands.
    - **Possible Planting Area (PPA) Impervious**: For this study, this represents areas of paved parking lot surfaces where it is feasible to establish tree canopy.

- **Unsuitable UTC**: Areas where it is unrealistic or undesirable to plant trees including roads, buildings, sports fields, agricultural lands, golf course fairways & greens, and near airport runways.

Ecosystem Services Terms & Acronyms

- **Ecosystem Services or Benefits**: The direct and indirect affects that trees have on the economy, environment, and human health. This assessment analyzed four types of ecosystem services (air quality improvement, energy conservation, stormwater mitigation and carbon storage/sequestration). However, there are many others.
- **i-Tree:** A state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban forest inventory, analysis, and benefits assessment tools.
  - **i-Eco**: A module of the i-Tree suite which uses on-the-ground tree surveying and complex ecological modeling to estimate the amount of *ecosystem services* provided by trees in a study area. All ecosystem service values in this assessment come from i-Eco.
  - **i-Design:** A free web-based module of the i-Tree suite which uses inputs of location, species, tree size and condition to calculate individual tree benefits related to greenhouse gas mitigation, air quality improvements, energy savings and stormwater interception.

Tools for Strategic Canopy Development Terms & Acronyms

- **CommunityViz (CV)**: A software extension to ESRI's ArcGIS (extension means that it works within and 'sits on top of' ArcGIS). It is a comprehensive, dynamic, 2D and 3D software for urban planning. The Treasure Valley Urban Forest Scenario Tools were built using CommunityViz. See pages 19 & 40 and Appendix page C14.
- **Suitability Modeling**: The *CV* process of prioritizing and ranking areas based on how desirable they are for a certain activity. In this assessment census blocks and potential planting sites were ranked based on how desirable they are for new tree planting. The Suitability Model creates a score from 0-100 for census blocks based on numeric input criteria (aka, factors) that relate to a feature's desirability (e.g. the amount of PPA in a census block or proximity of a planting site to a major road or parking lot).

Other Terms & Acronyms

- **GIS – Geographic Information Systems**: Computer software for conducting spatial analysis and creating map products based on data layers with real-world coordinates. The GIS software used in this assessment is ArcGIS v10x from ESRI.
- **IDL – Idaho Department of Lands**: The Idaho state agency leading this assessment.
- **Treasure Valley:** For the purposes of this report, this is highly developed area of Canyon and Ada Counties that comprise the study area, or *Area of Interest* (see map page 3).

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Appendices

About Appendices:
Appendices contain information important for interpreting the report, but not core to the major

Appendix A: Land Cover & UTC Analysis

Detailed Land Cover Analysis Methods, Land Cover Accuracy Assessment Methods, and Results

Land cover classification from 2011 National Agriculture Inventory Program (NAIP) 4-band imagery was performed using Feature Analyst v5 Object Based Image Analysis (OBIA) classification software in combination with vector-based GIS data. The OBIA classes (tree canopy, non-forest vegetation, impervious surfaces and dry vegetation and soil) were overlaid with buildings and water digitized from the imagery, and roads and parking areas modified from vector data delivered by IDL. Non-forest vegetation was classified as irrigated and non-irrigated using an unsupervised classification algorithm. Feature Analyst was used to create a conifer/deciduous sub-class of tree canopy.

Treasure Valley's land cover classification error matrix.

Classification Data	Reference Data: Tree Canopy	Open Space/ Grass	Impervious	Soil / Dry Vegetation	Water	Total Reference Pixels
Tree Canopy	29	0	3	0	0	32
Open Space / Grass	1	71	1	6	0	79
Impervious	0	4	107	2	0	113
Soil / Dry Veg.	1	2	5	23	1	32
Water	0	0	0	0	7	7
Total	31	77	116	31	8	263

Overall Accuracy = 90%

Producer's Accuracy		User's Accuracy	
Tree Canopy	94%	Tree Canopy	91%
Open Space / Grass	92%	Open Space / Grass	90%
Impervious	92%	Impervious	95%
Soil / Dry Veg.	74%	Soil / Dry Veg.	72%
Water	88%	Water	100%

The classification error matrix describes how well the classification matches land cover objects as they occur on the landscape. Overall classification accuracy is 90% indicating that any pixel chosen at random from the classification will match the actual land cover 90% of the time. Accuracy ranges from 100% for water (which was manually digitized) to 72% for Soil / Dry Vegetation (difficulty in this class stems from similarities of dry and green vegetation, as well as confusion between compacted gravel and impervious surfaces).

Guide to Treasure Valley UTC Deliverables

Each city has its own folder with all of its own data. The folder structure is identical for all. Eagle is fully expanded as an example.

- Boise
- Caldwell
- Eagle
  - Imagery
    - Eagle_NAIP.img **:2011 National Agricultural Imagery Program Aerial Photography (Raster)**
  - Land_Cover
    - Eagle_Landcover.gdb
      - Eagle_BuildingFootprints **:Building Footprints (Vector)**
      - Eagle_LC_9class **:Classified Land cover (Raster)**
      - Eagle_ParkingLots **:Parking Lots land cover class separated into its own file (Vector)**
      - Eagle_Roads **:Roads land cover class separated into its own file (Vector)**
      - Eagle_Tree_Canopy **:Tree Canopy land cover class separated into its own file**
      - Eagle_UTC_6class **:UTC classes (UTC, PPA, Unsuitable etc.) (Raster)**
  - Reporting
    - ArcMap_MXDs and Layers **:Contains ArcMap MXD map documents and layer files**
    - Report **:Final project report and documentation (MS Word doc and Adobe PDF)**
    - Spreadsheet
      - Eagle UTC Assessment Results.xlsx **:UTC results spreadsheet (MS Excel)**
  - Tools
    - Eagle Tree Canopy Scenario Tools **: CommunityViz Databases and Analysis Folders**
      - 3D
      - Compare Images
      - Data
      - Reports
      - CVAnalysis.gdb
      - CVAnalysis.mxd
      - CVAnalysisInfo.xml
    - Eagle_UTC_Study_Maps.pdf **: Interactive PDF map book**
    - UTC_Calculator_Eagle.xlsm **:Canopy Calculator Tool**
  - UTC_Results
    - Eagle_UTC_Results.gdb
      - Eagle_City_Limits **:City boundary (1 poly) with calculated UTC & land cover metrics**
      - Eagle_Land_Use **:Land use classes (12 polys) with calculated UTC & land cover metrics**
      - Eagle_PlantingSites **:Potential planting sites**
      - TV_Census_Blocks_Eagle **:2010 Census Blocks with calculated UTC & land cover metrics**
      - TV_parcels_Eagle **:Tax assessors parcels with calculated UTC & land cover metrics**
      - TV_ROW_Eagle **:Right-of-Way segments with calculated UTC & land cover metrics**
- Garden City
- Kuna
- Meridian
- Middleton
- Nampa
- ProjectAOI
- Star
- Unincorporated Ada County
- Unincorporated Canyon County

Appendix B: Ecosystem Benefits Analysis

The i-Tree Eco software from the U.S. Forest Service provided the foundation of ecosystem services valuation for the TV UTC Assessment. i-Eco uses sophisticated environmental models to estimate annual ecosystem service benefits of tree canopy within a defined study area. Inputs to the model include an inventory of trees from field plots in the study area or individual trees (in a 100% sample), local precipitation data, and local air quality data. Plan-It Geo utilized state AQ monitoring stations, as well as a series of research-derived static lookup tables.

In order to quantify the ecosystem services of the existing tree canopy, scenarios of future tree canopy cover, and individual potential tree plantings, Plan-it Geo modeled numerous ecosystem benefit values on a per-species and per-unit-area basis. Methods are described below, followed by a summary of the results and a narrative on the science of how trees impact air quality.

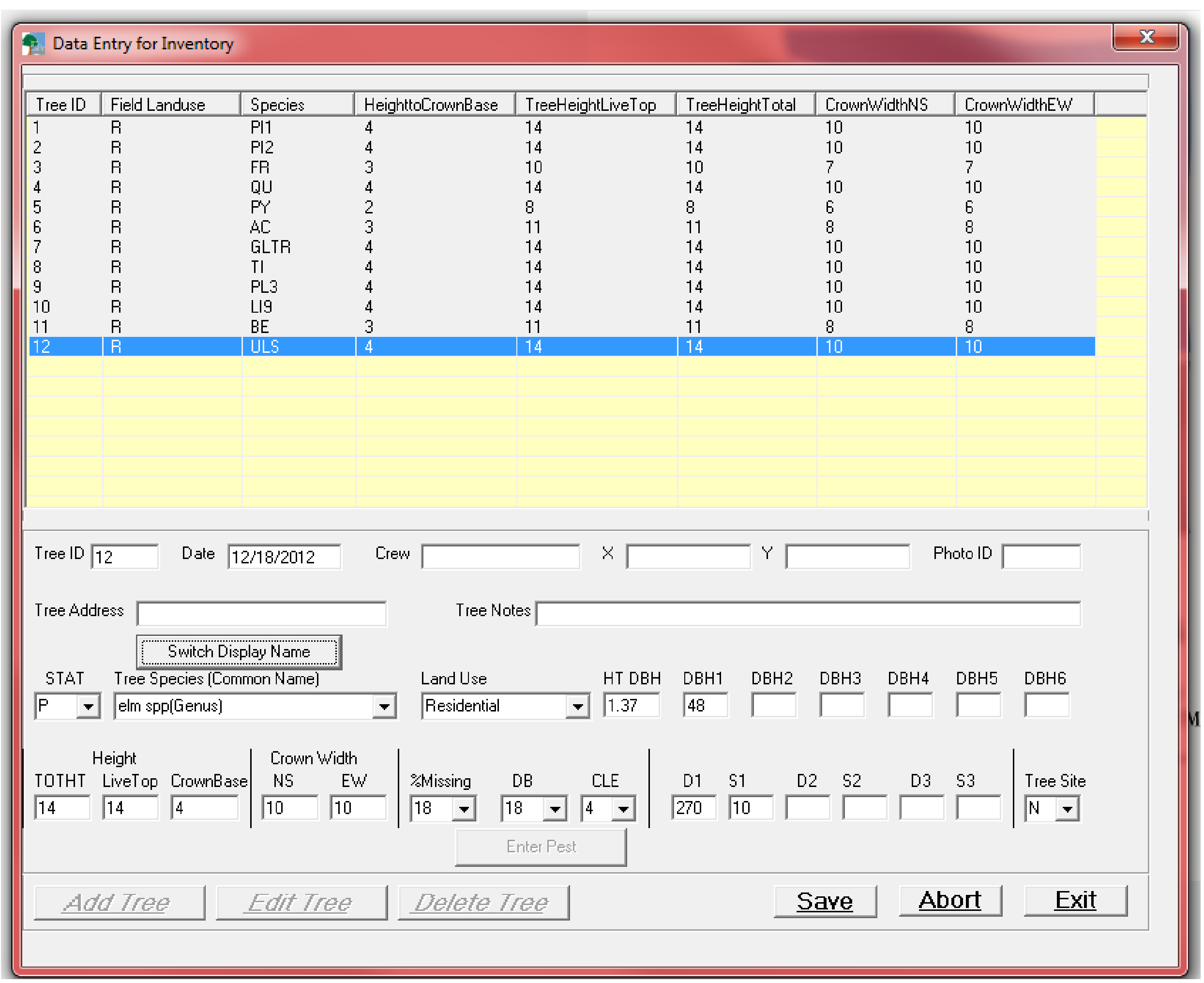
- ***Estimating Per Tree Benefits***
- ***Canopy Cover Scenario Modeling by Plot-Swapping***
- ***i-Tree Eco Results Summary***
- ***Modeling the Impact of Trees on Air Quality: Understanding the Science***

Estimating Per-Tree Benefits

Plan-It Geo also used i-Tree Eco in Inventory Mode to input hypothetical trees individually into the tree inventory for the model to consume. This differs from a traditional i-Tree Eco study, where sample plots are inventoried as a unit. The model used an idealized, hypothetical set of 12 trees, each belonging to a different genus. The 12 genera selected as the most important and applicable in the Treasure Valley include: Spruce (*picea*), Pine (*pinus*), Ash (*fraxinus)*, Oak (*quercus),* Pear (*pyrus*), Maple (*acer*), Locust (*gleditsia*), Linden a.k.a. Basswood (*tilia*),Sycamore (*platanus*), Sweetgum (*liquidambar*), Birch (*betula*), and Elm (*ulmus*). A description of how the 12 species were selected is on page C13.

Plan-It Geo created a growth curve estimating the height and DBH of each of these 12 trees at eight different five-year time intervals as they mature to forty years. Each five-year time period for the 12 trees was loaded into its own i-Eco assessment. The estimated height and DBH values were input into the data entry form for each tree and all other data fields were kept constant at reasonable values. Additionally, to model the impact of trees on energy savings, simulations were modified to represent a tree on the north, south, east, and west side of a home 10-meters away. An example of the interface is below.

The i-Tree Eco Data Entry Form


Data Entry for Inventory

Tree ID	Field Landuse	Species	HeighttoCrownBase	TreeHeightLiveTop	TreeHeightTotal	CrownWidthNS	CrownWidthEW
1	R	PI1	4	14	14	10	10
2	R	PI2	4	14	14	10	10
3	R	FR	3	10	10	7	7
4	R	QU	4	14	14	10	10
5	R	PY	2	8	8	6	6
6	R	AC	3	11	11	8	8
7	R	GLTR	4	14	14	10	10
8	R	TI	4	14	14	10	10
9	R	PL3	4	14	14	10	10
10	R	LI9	4	14	14	10	10
11	R	BE	3	11	11	8	8
12	R	ULS	4	14	14	10	10

Tree ID 12 Date 12/18/2012 Crew X Y Photo ID

Tree Address Tree Notes

Switch Display Name

STAT P | Tree Species (Common Name) elm spp(Genus) | Land Use Residential | HT DBH 1.37 | DBH1 48 | DBH2 | DBH3 | DBH4 | DBH5 | DBH6

Height TOTHT 14 LiveTop 14 CrownBase 4 | Crown Width NS 10 EW 10 | %Missing 18 | DB 18 | CLE 4 | D1 270 | S1 10 | D2 | S2 | D3 | S3 | Tree Site N

Enter Pest

Add Tree | Edit Tree | Delete Tree | Save | Abort | Exit

The i-Eco assessments together track the ecosystem services provided by 12 trees throughout their lifespan. Because i-Tree Eco reports ecosystem service benefits on a per-species basis and the simulated inventory had only one tree of each species, the per-species values reported were interpreted as per-tree values. Multiplying the annual, per-tree benefit values in each time period by the constant five years per time-period gives an estimate of the cumulative, or lifetime, services provided by each tree during that time-period.

These five-year cumulative values were summed and incorporated into the CV scenario tools to estimate the total benefits that a tree provides at any age. Benefit values at 40 years of age were used as a constant for trees over 40 years old in the scenario modeling tool.

Canopy Cover Scenario Modeling by Plot-Swapping

Based on the field measurements collected during the 2011 i-Eco survey, Plan-It Geo modeled the value of ecosystem services under multiple canopy cover percent scenarios. To do so, i-Eco plots with low or no canopy were "swapped" with plots with more mature canopy to create desired combinations of canopy cover and tree structure. The original inventory had 7.3% canopy cover. Scenarios were developed to characterize regional tree canopy cover at 10%, 15%, 20%, and 25%.

In order to achieve the target tree cover percentage, original i-Eco plots with low tree density were replaced with plots having larger tree canopy cover. A recursive algorithm was developed to determine the best plot replacement combination, which in general produced an inventory tree cover within a tenth of percent from the target tree cover percentage. A few rules were also adopted to maintain some degree of consistency with the original distribution of vegetation within the urban area:

1) Plots were swapped only within the same land use type (LUT)
2) Plots were swapped only if the tree cover area of the replacing plot was equal or less than the sum of actual tree cover and plantable areas in the to-be-replaced plot.
3) The relative fraction of tree cover area in each LUT with respect of total tree cover area was maintained as close as possible to the one observed in the original inventory.

Rules 1 and 2 were strictly enforced to maintain a consistency with the original tree distribution in the area. However, because the swapping of plots causes only finite changes in tree cover percentage (which may not necessarily produce a combination with the targeted inventory tree cover percentage), the relative fraction of tree cover area in each LUT was allowed to be adjusted (hence softening rule 3) when the recursive swapping algorithm approached the targeted inventory tree cover. In other words, our scenarios simulated management practices where more trees were planted in areas that already allowed the planting of more trees and that favored LUT where trees were already present (e.g., residential vs. industrial) and only occasionally and marginally increased the relative importance of some LUT with respect the original inventory.

i-Tree Eco Results Summary

i-Eco results are summarized on the next two pages based on the methods presented above.

Across the TV region, scenarios were developed from the original i-Eco estimate of canopy cover percent (7.3%) up to 25% tree canopy in 5% increments as described in the “plot swapping” methods above. The table below identifies the air pollutants removed by the canopy in short tons/year for each scenario. The number of trees and associated leaf area (surface area) resulting from i-Eco based on the plot swapping method is also shown.

Tree Cover % Scenario	Original (7.3%)	10%	15%	20%	25%	Tons of air pollutants removed for every 1% of tree canopy increase in the region
Leaf Area (mi^2)	119	152	200	225	229	
No. Trees	2.4M	3.5M	4.3M	4.7M	5.0M	
CO	16.2	19.8	29.9	43.2	46.2	1.8
NO_2	30.7	36.8	54.0	76.5	88,2	3.4
O_3	276.3	333.4	489.0	696.3	782.1	30.3
PM_{10}	256.8	301.3	438.2	613.3	765.4	29.5
$PM_{2.5}$	13.2	14.0	20.1	25.8	44.9	1.7
SO_2	0.5	0.6	0.9	1.3	1.7	0.07

M = millions

On the next page, three different i-Tree Eco result values are summarized. The first (i) provides a broad cross-section of results based on the original plot-based field inventory in terms of structure, function, and value. The second (ii) specifically quantifies the impact on air quality standards provided under tree canopy percent scenario from the modified plots. The third (iii) presents the cumulative (lifetime) values for the 12 select tree species over a 50-year period using i-Eco “Inventory Mode” method.

Summary of i-Tree Eco Results Regionally and for 12 Modeled Species

(i) Benefit values modeled in i-Tree Eco version 5.0.6 for the Treasure Valley urban forest:

Structure (of the trees)

- Estimated 2.4 Million trees
- Most important species by leaf area and composition: *Black locust, Blue spruce, cottonwod, Austrian pine, Northern white cedar, honeylocust, apple*
- 51% of all trees are <6" DBH
- 32% of all trees are between 6 - 12" DBH

Function (Annual Benefits)

- Removes 581 tons of air pollutants (270 tons of O3, 245 tons of PM 10, and 15 tons of PM 2.5)
- Mitigates 125 Million gallons of stormwater
- Conserves 11,641 MWH of electricity for cooling; results in -96,830 MBTU of natural gas for heating
- CO^2 Sequestration: 15.5 thousand tons

Value (Annual $ Benefits)

- $7.5M in total air pollution mitigation benefits, including: $4M from PM 10; $2.9 Million from PM 2.5; and $.7M from O3 reductions
- $936K in summer cooling benefit and -$1.15 Million in winter heating for -$213,420 net energy impact
- $1.1 Million in stormwater runoff mitigation savings

(ii) Modified i-Eco database (run in v5.0.6) for air quality benefits under increased canopy percent scenarios:

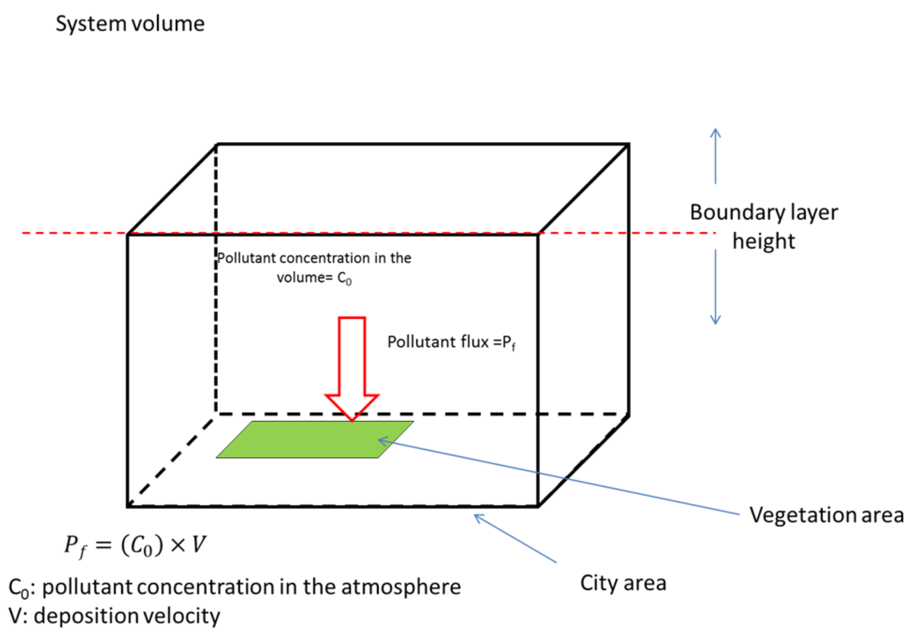
Pollutant	NAAQS -Primary	Original	10%	15%	20%	25%
Carbon Monoxide (CO)	Annual 8-hour Max (ppm)	2.375	2.375	2.375	2.375	2,375
	Annual 1-hour Max (ppm)	5.3	5.3	5.3	5.3	5.3
Nitrogen Dioxide (NO_2)	98th percentile of daily max distribution (ppb)	24.98	24.99	24.98	24.98	24.97
	Annual mean (ppb)	7.45	7.50	7.50	7.50	7.50
Ozone (O_3)	Annual fourth-highest daily maximum (ppb)	68.375	68.29	68.25	68.23	68.16
Particle Pollution =2.5 µm ($PM_{2.5}$)	Annual mean (µg/m^3)	11.49	10.53	10.53	10.53	10.52
	98th percentile of daily average distribution (µg/m^3)	87.35	87.25	87.20	87.18	86.95
Particle pollution =10 µm (PM_{10})	Annual daily max average (µg/m^3)	90.0 74.6	89.5 74.4	89.3 74.3	89.1 74.3	88.5 74.1
Sulfur Dioxide (SO_2)	99th percentile of daily maximum (ppb)	8.62	8.8	8.8	8.8	8.8

(iii) Benefit values modeled in i-Eco "Inventory Mode" for 12 select tree species

Tree Age	Storm Water (ga)	Storm Water ($)	Ozone (lbs)	Ozone ($)	PM 10 (lbs)	PM 10 ($)	PM 2.5 (lbs)	PM 2.5 ($)	AQ Total (lbs)	AQ Total ($)	Avg. Energy ($)	Avg. Energy (kWh)	Avg. Cooling ($)	Avg. Heating ($)	Total Savings ($)
5	10	$0.09	0.05	$0.07	0.04	$0.34	0.00	$0.23	0.10	$0.64	$0.00	0	$0.00	$0.00	$0.73
10	76	$0.67	0.38	$0.52	0.32	$2.42	0.01	$1.62	0.78	$4.58	$0.00	0	$0.00	$0.00	$5.25
15	240	$2.13	1.18	$1.61	1.02	$8.19	0.05	$5.59	2.46	$15.47	$22.16	286	$20.31	$1.86	$39.77
20	507	$4.51	2.46	$3.36	2.21	$17.87	0.11	$12.26	5.22	$33.65	$71.67	978	$70.33	$1.34	$109.83
25	950	$8.45	4.63	$6.32	4.12	$33.21	0.21	$22.75	9.78	$62.59	$130.58	1,961	$142.51	-$11.92	$201.61
30	1,502	$13.35	7.33	$10.02	6.41	$51.66	0.32	$35.40	15.39	$97.59	$235.44	3,560	$259.60	-$24.16	$346.39
35	2,231	$19.85	10.82	$14.81	9.40	$76.96	2.83	$53.11	25.04	$145.64	$343.09	5,245	$383.64	-$40.54	$508.58
40	3,202	$28.48	15.51	$21.23	13.48	$111.87	3.05	$77.73	34.89	$211.93	$463.45	7,080	$518.47	-$55.02	$703.86
45	4,172	$37.11	20.21	$27.66	17.56	$146.79	3.27	$102.35	44.75	$278.22	$583.81	8,915	$653.31	-$69.49	$899.15
50	5,143	$45.75	24.91	$34.08	21.63	$181.71	3.49	$126.96	54.60	$344.51	$704.18	10,750	$788.14	-$83.97	$1,094.43

Modeling the Impact of Trees on Air Quality: Understanding the Science

Vegetation has an important role in direct removal of pollutants from the urban atmosphere. It can potentially reduce the total concentration of air pollutants in the atmosphere by sequestering pollutant particles reaching the surface of leaves. The total amount of pollutants deposited on the vegetation depends on many factors, including type of pollutant, type of vegetation, pollutant concentration in the atmosphere and atmospheric conditions. I-Eco estimates pollutant deposition on vegetation by assuming that the deposition flux (change) is positively dependent on the atmospheric concentration of the pollutant and on the deposition velocity which account for many of the other deposition drivers (e.g., atmospheric conditions, vegetation type and amount, etc.). As benefits are quantified by the total amount of pollutant removed, another important parameter is the volume that i-Eco uses as a model domain for the pollutant removal. This 'system' volume is in general bounded by the area considered (e.g., the area of the city), and by a vertical height (i.e., the boundary layer height) that can vary from few hundred to couple of thousand feet, depending on atmospheric conditions.

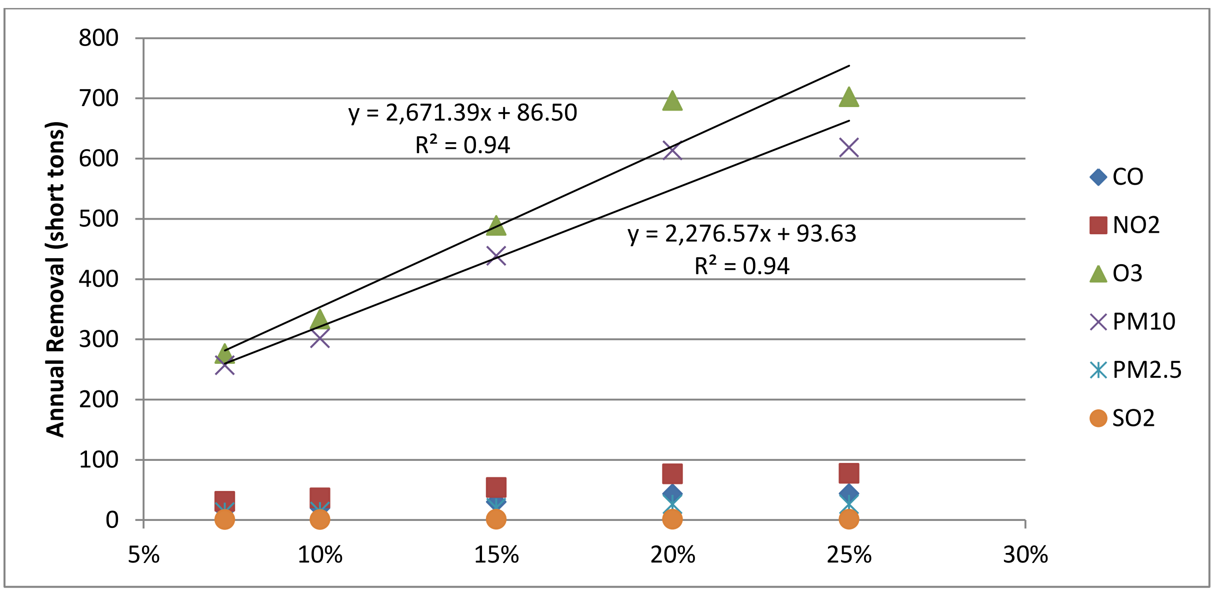


In order to correctly interpret the results from i-Eco, in particular those concerning pollutant depositions, it is important to consider that i-Eco assumes that the system volume is well mixed with respect of pollutant and therefore concentration of any simulated pollutant is the same within the entire system volume. This assumption, while somewhat necessary to estimate deposition fluxes, significantly reduces the spatial resolution of the i-Eco model and oversimplifies the very spatially heterogeneous pollutant concentrations that are typical of an urban environment. For instance, many pollutant sources are located very close to the lowest surface of the volume (e.g., fugitive and non-fugitive emissions from mobile sources, like cars) and the typical dense urban structure impose pathways to pollutant dispersion that are not conducive to well mixed boundary layers.

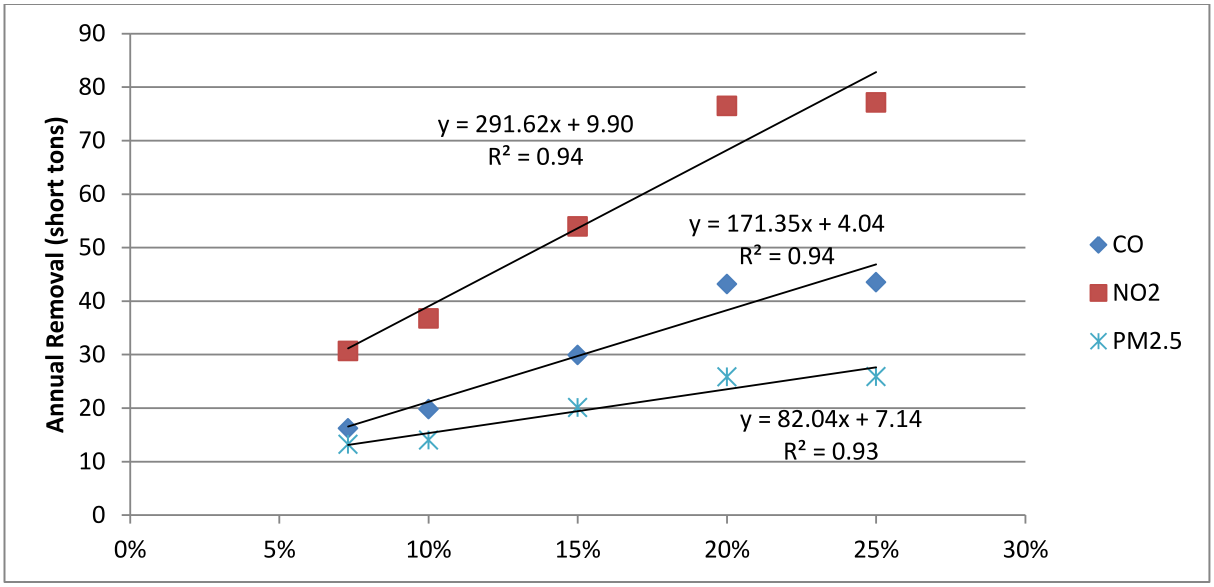
It is reasonable to assume that in general more vegetation in the urban environment will result in a much larger deposition of pollutant and therefore higher benefits in air quality (AQ). However, the specific relationship between increases in vegetation and increases in pollutant deposition is largely unknown, leading to uncertainty in developing strategies to control for AQ by using vegetation management. Further complicating this issue, many approaches can be used to asses AQ and AQ benefits from urban vegetation. The i-Eco model provides the most immediate tool for modeling AQ benefits related to the quantity of vegetation, namely the total amount of pollutants removed by vegetation (per unit of time) and associated monetary benefits. However, another common approach is to quantify the change in pollutant concentration due to changes in vegetation. This approach directly relates to the National Ambient Air Quality Standards (NAAQS) that the U.S. Environmental Protection Agency set for six principal pollutants (http://www.epa.gov/air/criteria.html). These standards are developed based on health (primary standard) and welfare (secondary) protection considerations, and are used to determine the AQ conditions of given locations and ultimately (non-)attainment conditions.

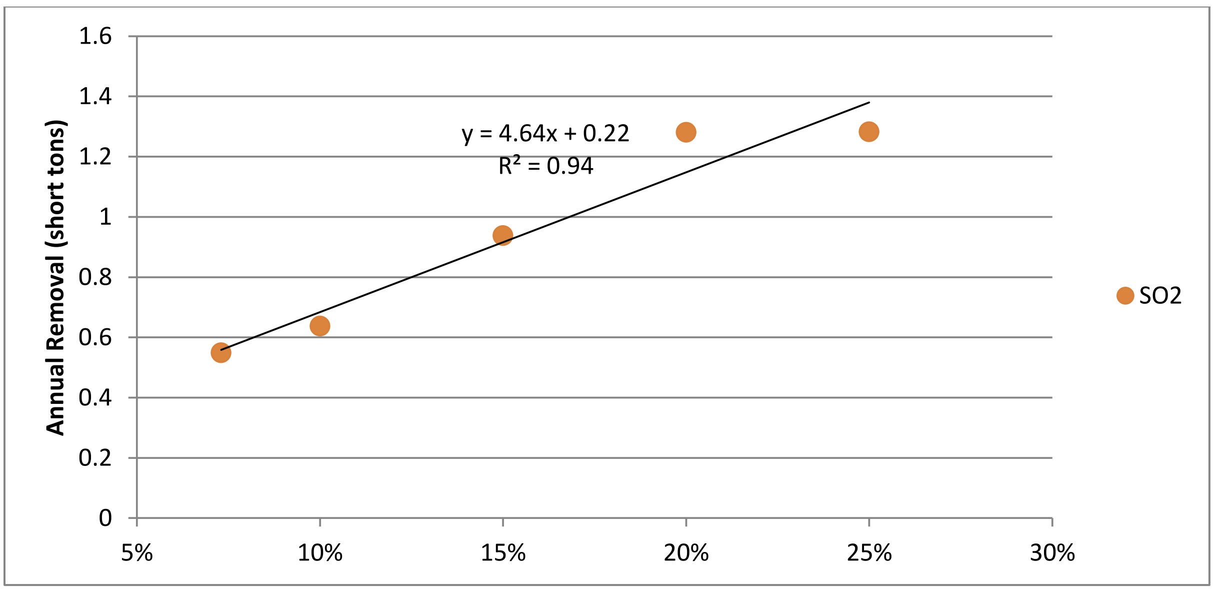
The amount of pollutant removed by vegetation clearly depends to some extent on the type of pollutant and its concentration. Ozone and PM_{10} have the largest amount removed by vegetation, followed by NO_2, CO, $PM_{2.5}$ and SO_2.

Within the same pollutant, the effect of increasing vegetation is quite evident. For instance, for every percentage point that vegetation is increased, about 27 tons of O_3 are additionally removed from the atmosphere. The figures below graphically describe this concept.



In the figure on the following page, NO_2, CO, $PM_{2.5}$, and SO_2 are only shown to provide a sense of the difference in the magnitude of pollutant removal among pollutant types. The two figures describe the same results, but with different y-axis scales, providing a better resolution for these pollutants.





The table on the following page describes the current primary EPA-NAAQS for each pollutant and, briefly, the type of calculations used in deriving the NAAQS (e.g., type of average, percentile, etc…, also referred as the 'form'). Several pollutants have more than one primary NAAQS. This usually reflects the necessity of monitoring both short-term variability in concentration (e.g., hourly) and long-term, or ambient, conditions. Also, it is important to notice that many of these ambient NAAQS require 3 years of data. However, as the current version of i-Eco can only work with one year of AQ data, we only presented the results from that single year.

Pollutant	Averaging time	Form	NAAQS -Primary
Carbon Monoxide (CO)	8-hour	Not to exceed more than once per year	9ppm
	1-hour	Not to exceed more than once per year	35 ppm
Nitrogen Dioxide (NO_2)	1-hour	98th percentile of daily maximum distribution, averaged over 3 years, not to exceed	100 ppb
	Annual Mean	Not to exceed	53 ppb
Ozone (O_3)	8-hour	Annual fourth-highest daily maximum, averaged over 3 years, not to exceed	0.075ppm
Particle Pollution ≤2.5 µm ($PM_{2.5}$)	Annual	Averaged over 3 year not to exceed	12 µg/m³
	24-hour	98th percentile, averaged over 3 year, not to exceed	35 µg/m³
Particle pollution ≤10 µm (PM_{10})	24-hour	Not to exceed more than once per year, on average over 3 year	150 µg/m³
Sulfur Dioxide (SO_2)	1-hour	99th percentile of daily maximum, averaged over 3 years, not to exceed	75 ppb

The table below describes the values for the NAAQS (i.e., the design values) obtained under the different tree canopy scenarios. For PM_{10}, two monitoring stations were used in i-Eco and therefore two design values are available.

Pollutant	NAAQS -Primary	Original		10%		15%		20%		25%	
Carbon Monoxide (CO)	Annual 8-hour Max (ppm)	2.375		2.375		2.375		2.375		2,375	
	Annual 1-hour Max (ppm)	5.3		5.3		5.3		5.3		5.3	
Nitrogen Dioxide (NO_2)	98th percentile of daily max distribution (ppb)	24.98		24.99		24.98		24.98		24.98	
	Annual mean (ppb)	7.45		7.50		7.50		7.50		7.50	
Ozone (O_3)	Annual fourth-highest daily maximum (ppb)	68.375		68.29		68.25		68.23		68.22	
Particle Pollution ≤2.5 µm ($PM_{2.5}$)	Annual mean (µg/m³)	11.49		10.53		10.53		10.53		10.53	
	98th percentile of daily average distribution (µg/m³)	87.35		87.25		87.20		87.18		87.18	
Particle pollution ≤10 µm (PM_{10})	Annual daily max average (µg/m³)	90.0	74.6	89.5	74.4	89.3	74.3	89.1	74.3	89.1	74.3
Sulfur Dioxide (SO_2)	99th percentile of daily maximum (ppb)	8.62		8.8		8.8		8.8		8.8	

For all pollutants, the difference in design values under the different scenario is very low, if not insignificant. CO, NO_2, and SO_2 do not show any significant decrease in NAAQS, even though the i-Eco model reports larger amounts of pollutants being removed from the atmosphere under increasing canopy cover. Ozone shows a very small decline in its annual fourth highest daily maximum (less than 1% between the original and the 25% canopy cover scenarios). $PM_{2.5}$ shows a decline in its annual 98th percentile of daily average distribution (less than 1%) but not in its annual mean. PM_{10} shows a very small decline in its annual average (less than 1% between the original and then 25% tree cover scenario).

The apparent contradiction with the consistent increase in pollutant removal as tree canopy cover increases in the different scenarios can be explained by different factors. First, the use of NAAQS may not be the most efficient way to investigate the effect of increasing vegetation in AQ. NAAQS, because of their focus on human health and welfare, primarily focus on the highest concentration events in the datasets (short-terms peaks in pollutant concentrations) or long-term average (ambient conditions). The effect of vegetation seems to be small on an hourly basis, but consistent across the entire year, and may not be enhanced by the NAAQ statistics. As mentioned, a problem with spatial scales and resolution used in the i-Eco model may also be an important factor in potentially downplaying the effects of vegetation on AQ. In particular, we believe the problem may be related to the assumptions and methodologies adopted in i-Eco modeling in determining the overall volume of the model domain and how this volume is then used to calculate the efficiency of pollutant removal. A few reminders of how i-Eco (UFORE) works are necessary at this point.

The overall relation to estimate dry deposition is

$$F = V_d \cdot C$$

Where

F = pollutant flux (g m-2 h-1)

V_d = Deposition velocity (m s-1)

C = Air pollutant concentration (g m^{-3})

C is provided through monitoring stations, while V_d is estimated and is mainly a property of atmospheric and vegetation conditions. It is important to notice that none of the equations used to estimate V_d require the urban mixing height as a parameter. Finally, F is provided as function of vegetation area (m^{-2}) which can be easily translated into flux per city area by knowing both the area covered by the vegetation and the total area of the urban surface modeled in i-Eco. The estimate of the total mass of pollutant removed from the atmosphere (e.g., tons per hour, R_{tot}), can be calculated as

$$R_{tot} = A_v \cdot F$$

Where A_v is the vegetation area (m^2).

The efficiency of pollutant removal (also defined as the air quality improvement) is therefore defined as the total mass of pollutant removed (R_{tot}) divided by the total mass of pollutant in the atmosphere

$$I = \frac{R_{tot}}{R_{tot} + M_{tot}}$$

Where M_{tot} is the total mass of pollutant in the atmosphere as

$$M_{tot} = H \cdot C$$

Where H is the height of the mixing urban layer (m, which can extend from a few hundred meters at night to couple of kilometers during the day).

Notice that this last equation relies on the assumption of fully mixed boundary layer, or in other words, that C is the same over the entire system volume of the model. This is a critical assumption for the i-Eco model ,and while partly supported by experimental work it simplifies the complexity of the spatial (vertical and horizontal) relation existing between pollutant sources, transport, sinks (the vegetation) and measurements within the complex urban environment.

Because the change in air pollution concentration (ΔC) due to vegetation effect can be calculated as

$$\Delta C = \frac{C}{1 - I} - C$$

It is now clear that the above assumption and, we believe, simplification may cause ΔC to be underestimated, and hence the effect of vegetation on AQ downplayed.

Appendix C: Tools for Strategic Canopy Development Scenarios

Tools for strategic canopy development scenarios offer a range of methods for setting and evaluating urban forest management goals and planning for trees at multiple scales. Details are provided in this appendix for the following products:

Plan-It Geo Canopy Calculator

Along with a CommunityViz software tutorial, determining potential planting sites, and the 75th percentile rule as guiding tools for canopy development, Plan-it Geo built and delivered Excel-based Canopy Calculators for each city within the Treasure Valley study area and for the full area. This plug ‘n play tool allows management planners to enter various canopy goals based on land use, and determine the number of trees required to meet that goal.

Click Here to Edit UTC Goals

Boise, Idaho

Land Use Classes	Current: Total Land (Acres)	Existing UTC (Acres)	Existing UTC (%)	Total Possible Planting Area (Acres)	Total Possible Planting Area (%)	Goals: Urban Tree Canopy (%)	Urban Tree Canopy (No. Trees)
Agriculture	1,404	56	4.0%	24	2%	3%	-
Commercial	6,009	482	8.0%	3,112	52%	10%	-
Industrial	862	47	5.5%	553	64%	5%	-
Open Space	1,446	164	11.3%	1,079	75%	15%	-
Other	1,377	21	1.5%	1,074	78%	10%	-
Parks	1,129	287	25.4%	638	57%	20%	-
Public	6,802	400	5.9%	4,154	61%	10%	-
Residential High	1,932	417	21.6%	389	20%	20%	-
Residential Low	4,226	931	22.0%	2,515	60%	15%	-
Residential Medium	11,664	3,360	28.8%	3,481	30%	25%	-
Rights-of-Way	7,565	923	12.2%	953	13%	10%	-
Schools	810	60	7.4%	447	55%	10%	-
Citywide Total	**45,226**	**7,149**	**16%**	**18,418**	**41%**	**15%**	**61,711**

Predictions

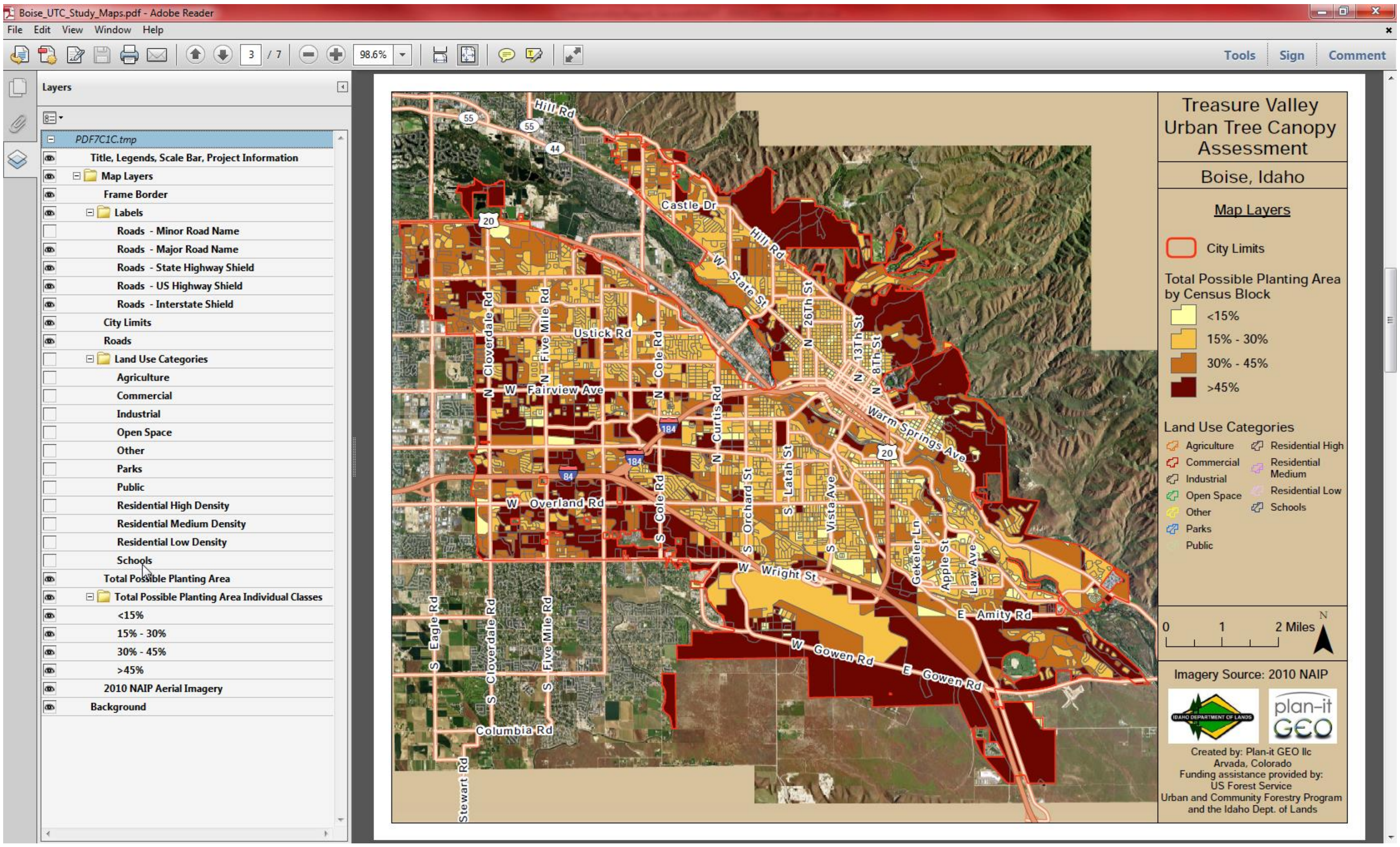
(+) Natural Regeneration (Acres)	(%)	(+/-) Canopy Growth & Mortality (Acres)	(%)	(-) Loss to Development (Acres)	(%)	(+) Tree Planting Required (Acres)	(No. Trees)	Net UTC Increase (Acres)	(%)	(=) UTC in 2043 (Acres)	(%)
1	1%	(15)	-26%	(25)	-45%	26	1,199	(14)	-25%	42	3%
93	19%	(125)	-26%	(25)	-5%	181	8,447	119	25%	601	10%
17	35%	(12)	-26%	(25)	-53%	17	804	(4)	-8%	43	5%
32	20%	(43)	-26%	(25)	-15%	91	4,234	53	32%	217	15%
32	153%	(5)	-26%	(25)	-119%	118	5,517	117	556%	138	10%
19	7%	(75)	-26%	(25)	-9%	20	929	(61)	-21%	226	20%
125	31%	(104)	-26%	(25)	-6%	293	13,664	280	70%	680	10%
12	3%	(109)	-26%	(25)	-6%	94	4,381	(31)	-7%	386	20%
75	8%	(242)	-26%	(25)	-3%	-	-	(297)	-32%	634	15%
104	3%	(875)	-26%	(25)	-1%	362	16,855	(444)	-13%	2,916	25%
29	3%	(240)	-26%	(25)	-3%	72	3,368	(167)	-18%	757	10%
13	22%	(16)	-26%	(25)	-42%	50	2,314	21	35%	81	10%
553	**8%**	**(1,861)**	**-26%**	**(300)**	**-4%**	**1,324**	**61,711**	**(427)**	**-6%**	**6,721**	**15%**

*Change Calculated after 30 Years

*Regeneration, Growth, Mortality, and Loss may result in negative Planting numbers

Interactive PDF Maps

Plan-it Geo developed and delivered Adobe Reader-based Geo PDF maps to assist management planners visualize and implement tree canopy growth and preservation strategies. The image below depicts how a PDF map may be used to turn on and off various layers such as canopy cover and PPA land cover layers to make custom maps.



Detailed Potential Tree Planting Sites Methodology

In three sections, this outline describes (A) criteria and rules used to map GIS locations of potential planting points, (B) priority factors (aka, GIS data layers and criteria) overlaid with planting site points to create attributes used to query, select, symbolize, and rank sites for suitability scores (0-100 value), and (C) similar priority factors and attribute fields, but not all identical, added to the 2010 census block polygons for tree planting suitability analysis in the TV region.

(A) **Mapping Potential Planting Sites** – Criteria and GIS Rule Sets used:

1. Exclusion Data:
    a. Boise Fire Hydrants – Buffer 8ft
    b. Street Intersections – Buffer 15ft
    c. Buildings – Buffer 5ft
    d. Tree Canopy – Buffer 10ft
    e. Agriculture Land Use – Buffer -15ft, subtract ring buffer 5-50ft from Buildings so those planting areas are not excluded
2. Creation of Potential Planting Sites:
    a. Subtract exclusion data polygons from the irrigated and non-irrigated vegetation class from the land cover data
    b. Create fishnet (GIS grid) and intersect this with the remaining "plantable" vegetation polygons (i.e. the result from the above step)
    c. Generate centroids of fishnet grid cells for planting site GIS point locations

(B) **Potential Planting Site Points** – Suitability Factors (aka, criteria or attributes):

1. Land Cover Metrics and Land Use type per point
    a. UTC %, Impervious %, PPA Impervious %, PPA Veg %, and Land Use type were joined from the Parcels_UTC data set.
        i. The specific fields from that data set used are, respectively: Parcel_UTC_Pct, Parcel_Imp_Pct, Parcel_PPAImp_Pct, Parcel_PPAVeg_Pct, and Land Use types of Residential, Commercial, Public, OpenSpace, Industrial, School, Park, ROW
    b. Joined from Parcels based on a Select by Location (Intersect) with Planting Site points
    c. If Planting Site Point is not within a Parcel, it was assumed to be within Right of Way.
    d. For CommunityViz, separate fields are provided for each Land Use type with a '1' given to the point that fell in a particular land use and '0' if it did not fall in that land use.
2. Neighborhood (Boise only)
    a. Name is joined from the Boise Neighborhood in which the Planting Site Point resides

b. If Planting Site Point is not within a Neighborhood, it is assigned 'N/A'

3. City Limits (City)
    a. Name is joined from City Boundary in which the Planting Site Point resides
4. Energy
    a. Raster process to determine vegetated areas within 50ft of buildings and on SW, W, or NW aspect of a building
    b. Tree canopy polygons buffered by 10ft and subtracted from resultant vegetation raster
    c. Planting Site Points that intersect Energy Conservation Polygons = 1
    d. All other Planting Site Points = 0
5. Transportation
    a. Highways and Air Quality (AirQuality)
        i. Planting Site Points within 100ft of Expressway, Interstate, Principal Arterial, State Highway, and U.S. Highway type roads or within 50ft of Parking Lots = 1
        ii. All other Planting Site Points = 0
    b. Residential Street Trees (StreetTree)
        i. Planting Site Points that intersect Right of Way and within 15ft of Residential Parcels = 1
        ii. All other Planting Site Points = 0
    c. Rights-of-Way (ROW)
        i. Described above under Land use
6. Schools (School)
    a. Planting Site Points with Land Use from Parcel of School or within 250ft of a School = 1
    b. All other Planting Site Points = 0
7. Parks (Park)
    a. Planting Site Points with Land Use from Parcel of Park or within 250ft of Park = 1
    b. All other Planting Site Points = 0
8. Public Transit
    a. Planting Site Points within 50ft of Regional Bus Stops = 1
    b. All other Planting Site Points = 0
9. Owner/Renter (Owned)
    a. Planting Site Points that intersect Owner/Renter Occupied Housing = 1
    b. All other Planting Site Points = 0
10. Riparian
    a. Planting Site Points within 50ft of Floods, Wetlands, or Large Water Features = 1
    b. All other Planting Site Points = 0
11. Developed
    a. Planting Site Points within 50ft of Buildings, Right of Way, <u>or</u> Parking Lots = 1

    b. All other Planting Site Points = 0

(C) Census Blocks – Suitability Factors:

1. Land Use Categories (OpenSpace, Residential, Commercial, Industrial, Public, Park, School, ROW)
    a. Joined from Parcels that intersect with Census Block. Census Block can have multiple Land Use Categories due to multiple Parcels intersecting with a single Census Block
    b. Any Census Blocks that did not join with Parcels are considered Right of Way
2. Neighborhood (Boise only)
    a. Joined from Boise Neighborhood with which the Census Block intersects
    b. If Census Block does not intersect with a Neighborhood, it is assigned 'N/A'
3. Energy (2 attributes: Energy_Pct and Energy_Ratio)
    a. Buffer Buildings by 50ft and subtract Tree Canopy buffered by 10ft from the Building buffer
    b. Calculate the PPA Veg % within the resultant Building buffer area, summarized for each Census Block and joined back to the Census Block's new 'Energy' field.
    c. Essentially this is the % of planting space vegetation after excluding a 10ft buffer of trees that's within 50ft of buildings summarized per Census Block. It's a relative measure of planting potential near buildings for energy conservation benefits.
    d. Any Census Blocks without buildings or remaining planting space = 0%
    e. Then the ratio of building area to total census block area x the Energy % value above is calculated and used the suitability model. This is important because the % value above can be very high but in a census block with only one building.
4. Air Quality (AirQuality)
    a. Census Blocks that intersect Expressway, Interstate, Principal Arterial, State Highway, and U.S. Highway type roads or the Parking Lot field = 1
    b. All other Census Blocks = 0
5. Schools (School)
    a. Census Blocks with Land Use from Parcel of School or that intersect Schools = 1
    b. All other Census Blocks = 0
6. Parks (Park)
    a. Census Blocks with Land Use from Parcel of Park or that intersect Parks = 1
    b. All other Census Blocks = 0
7. Riparian
    a. Census Blocks within 50ft of Floods, Wetlands, or Large Water Features = 1
    b. All other Census Blocks = 0
8. Planting Site Count Air Quality (PS_Count_AQ)
    a. Number of Planting Site Points within each Census Block where Air Quality = 1

9. Planting Site Count Energy (PS_Count_Energy)
    a. Number of Planting Site Points within each Census Block where Energy = 1
10. Planting Site Count Parking Lot (PS_Count_ParkingLot)
    a. Number of Planting Site Points within each Census Block that intersect Parking Lots
11. Planting Site Count Total (PS_Count_Total)
    a. Total Number of Planting Site Points within each Census Block

Priority Tree Planting Suitability Model Factors

* Unless otherwise stated, factors apply to both census blocks (CB's) and potential planting sites

* SS = Suitability Score (a value between 0-100 calculated for each CB and each potential planting site (including 'proposed')

Factor	Data Source	Note (Query to Isolate Data/Rule to Use)	Prep Steps	Dynamic or Other
Existing UTC	Census Blocks& Parcels E-UTC %	%-UTC of census block, and use UTC-% from parcels for potential planting points	Spatial Join to potential planting sites	Hardcoded attribute in feature/target
Total Impervious Area (IA)	Census Blocks & Parcels Land Cover metric %	Land cover 'total' IA of census block, and use 'total' IA-% from parcels for potential planting points	Python script; UTC style model	Hardcoded attribute in feature/target layer
Irrigated Planting Area	Census Blocks & Parcels PPA Veg Irrig.	PPA Veg of census block, and use PPA Veg Irrig. % from parcels for potential planting points	Python script; UTC style model	Hardcoded attribute in feature/target layer
Total Veg Planting Area	Census Blocks & Parcels PPA Veg Total	PPA irrigated + non-irrigated of census block, and use same from parcels for potential planting points	Python script; UTC style model	Hardcoded attribute in feature/target layer
Total Planting Area	Census Blocks & Parcels PPA Total	PPA Impervious (parking lot area) + PPA Veg. Total (irrigated + non-irrigated areas)	Python script; UTC style model	Hardcoded attribute in feature/target layer
Parking Lots	Parking Lots	Plantings within 50-ft of parking lots and count of these per census block	Select by Location w/in 50' = 1, else = 0	Hardcoded attribute in feature/target layer
Air quality	Roads (arterials) and parking lots	Within 100-ft for arterials and 50-ft for parking lots; for CBs, use 'intersects' roads or parking lots.	Select by Location w/in 100' = 1, else = 0	Hardcoded attribute in feature/target layer
Energy Conservation	Buildings, Residential land use	% PPA Veg Total in a CB that's within 50-ft of residential buildings	Select by Location w/in 50' = 1, else = 0	Hardcoded attribute in feature/target
Residential	Land Use (fields for low, medium, and high density)	Select where LU = Residential, field calculate '1' in the new Residential field, else calculate '0'. Brian will use majority process for CBs.	Spatial Join or Select by Location and Field Calc.	Hardcoded attribute in feature/target layer

Commercial	Land use	Select where LU = Commercial, field calculate '1' in the new Commercial field, else calculate '0'. Brian will use majority process for CBs.	Spatial Join or Select by Location and Field Calc.	Hardcoded attribute in feature/target layer
Industrial	Land use	Select where LU = Industrial, field calculate '1' in the new Industrial field, else calculate '0'. Brian will use majority process for CBs.	Spatial Join or Select by Location and Field Calc.	Hardcoded attribute in feature/target layer
Public	Land use	Select where LU = Public, field calculate '1' in the new Public field, else calculate '0'. Brian will use majority process for CBs.	Spatial Join or Select by Location and Field Calc.	Hardcoded attribute in feature/target layer
Open Space	Land use	Select where LU = Open Space, field calculate '1' in the new Open Space field, else calculate '0'. Brian will use majority process for CBs.	Spatial Join or Select by Location and Field Calc.	Hardcoded attribute in feature/target layer
Schools	Land use and point layer	Select where LU = School, field calculate '1' in the new School field, else calculate '0'	Merge 3 into 1, then Select by Location w/in 250' = 1, else = 0	Hardcoded attribute in feature/target layer
Parks	Land use	Select where LU = Park, field calculate '1' in the new Park field, else calculate '0'. Brian will use majority process for CBs.	Select by Location w/in 100' = 1, else = 0	Hardcoded attribute in feature/target layer
Public Transportation	Bus Stop layers	Select by Location (Intersect) = 1, else 0 for CB's. Use within 50-ft for potential planting points	Select by Location w/in 50' = 1, else = 0	Hardcoded attribute in feature/target layer
Riparian and Floodplain	Streams, flood, and wetland layers	Buffer streams 50-ft/merge. If CB or planting points intersect then '1', else '0'.	Spatial Join or Select by Location and Field Calc.	Hardcoded attribute in feature/target layer
Housing Density	2010 Census Blocks	Join attribute value to each planting point; nothing for census blocks b/c that is the source of this value	Spatial Join or Select by Location and Field Calc.	Hardcoded attribute in feature/target layer
Population Density	2010 Census Blocks	Join attribute value to each planting point; nothing for census blocks b/c that is the source of this value	Spatial Join or Select by Location and Field Calc.	Hardcoded attribute in feature/target layer

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Modeling Tools for Strategic Canopy Development Scenarios: CommunityViz Documentation and Tutorial

By integrating Urban Tree Canopy (UTC) assessment data and i-Tree ecosystem services values, Plan-It Geo provided *Modeling Tools for Strategic Canopy Development Scenarios* for the Treasure Valley (TV) region, nine cities, and the Ada County Highway District (11 analyses in total). CommunityViz Scenario 360, a planning software extension for ArcGIS desktop, was chosen as the platform. This software was also used for COMPASS' *Communities in Motion 2040* Plan. This document describes the process and provides examples of how to use the GIS-based urban forest scenario tools. Generally speaking, these CommunityViz ("CV") tools allow a user to identify and prioritize areas for tree planting, track new or existing trees, projects, and costs, forecast future urban tree canopy (UTC) based on existing canopy growth and new plantings, and model the potential ecosystem services (benefits) over time.

This document is not intended to explain all of the functionality and components within CV software, but rather to explain how the TV CV Urban Forest Scenario Tools were developed and describe how they can be used. More information on the software and online help menu is provided at the end. This documentation provides an introductory overview, tips on getting started with CV, regional-scale tools including CV's "Suitability Model" used in the tools, site-specific tree cost/benefit tools, and specific step-by-step instructions of several "Saved Views" (described below in detail).

Table of Contents

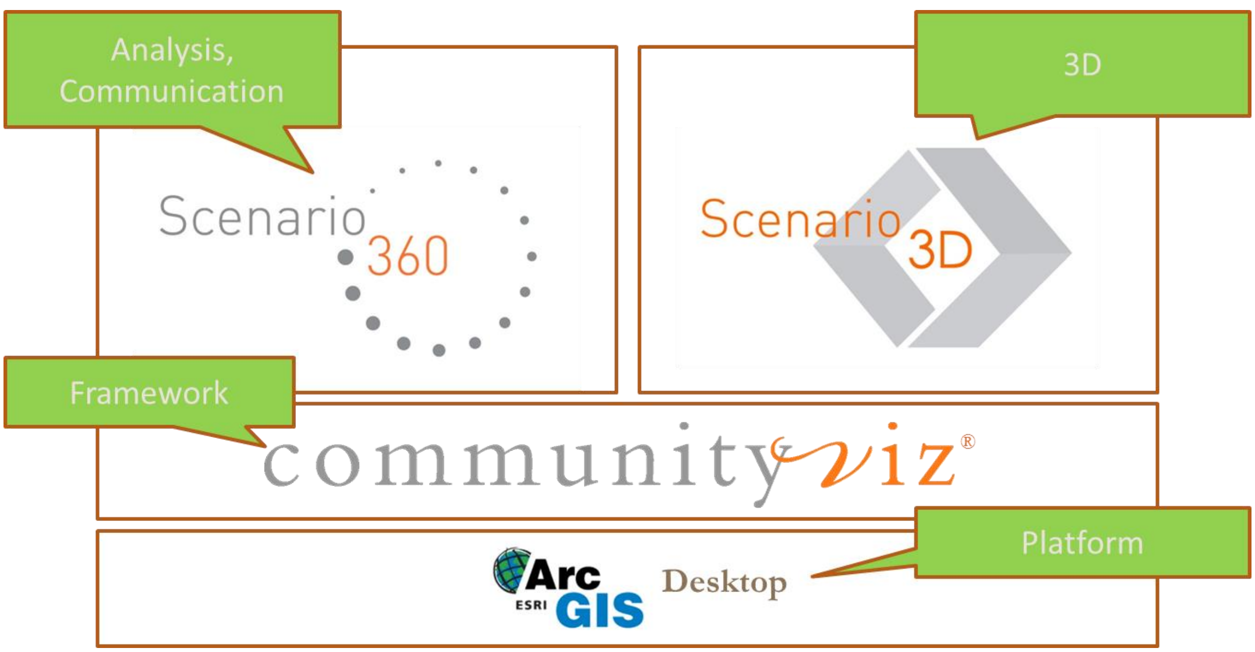
(1) Overview

This analysis and database allows a user to track, query, prioritize and symbolize tree planting opportunities in a GIS and ecosystem services toolset. This can be done at the regional or city-level using 2010 census blocks boundaries (polygons) or at the local site-scale using individual tree planting sites (points) and planting site boundaries (polygons). Project partners identified 12 trees species common in the Treasure Valley, and derived benefits for each of these in 5-year age increments over a 50-year life span using the US Forest Service software i-Tree (specifically i-Tree Eco's "Inventory Mode" option). Tree costs at the site-level scale are added by the user when adding planting site boundaries and new trees. In this way, a cost/benefit analysis can be done at the site-specific level.

To begin, below is a list of the main GIS-based components of the TV CommunityViz (CV) analysis tools with a brief description, along with GIS data layers included in the analysis. Additional GIS data or tables can be added to the analyses by the user at any time.

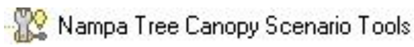
- Assumptions: slider bars or dropdown menus that allow users to select the criteria on which results of an analysis are based
- Charts: display the results of an analysis based on the assumptions, or criteria, the user selects. Indicator formulas, such as summaries or percentages, do the calculations in the background that get displayed in the charts.
- Data: CV "Dynamic" GIS Layers—these are GIS layers with special dynamic attribute fields in which data changes dynamically based upon the assumptions/criteria a user selects
    - Census Blocks ("CB" or "CBs")
    - Tree Plantings
    - Planting Site Boundaries
    - Tables with i-Tree benefit values for numerous ecosystem services
- Other Data: Reference Layers—GIS layers that are not used in the Scenario 360 analysis, but which can be used for reference as base map information, or for standard definition queries
    - Project Area of Interest (AOI)
    - City limits
    - Major roads
    - Parcels with UTC metrics
    - Potential Planting Locations: 'All' sites and 'Developed' sites (within 100' of developed features such as buildings and roads)
    - Neighborhoods (Boise only)
- Dynamic Attribute Formulas: fields performing calculations to dynamic GIS layers (see below)
- Indicators: formulas used to summarize dynamic attribute fields

- IsSelected: formula used to show impacts only of the selected records in tree plantings or CBs
- Reports: export a list of every component of the analysis with descriptions
- Saved Views: saves a view in ArcMap including the extent, layer symbology, charts, and slider bars (Assumptions). This creates an easy way to bring up all the tools needed to run models for specific purposes. *Saved Views are used throughout this documentation.*
- Scenarios: creates a copy of records in the dynamic layers and is controlled with a Definition Query with the Scenario name; allows users to change Assumptions or add/delete features to see the impact on Indicators/Charts and Compare Scenarios
- Styles: attribute painters, e.g. a tool that allows you to change the species of one tree by "painting" a different one over it. The associated benefits in the charts update using the attributes for the new species and get values change accordingly in the benefits charts. See page XX for a set of tree species styles.
- Wizards: models that automatically create Dynamic Attributes, Indicators, and Assumptions
    - Suitability Model – used for tree planting prioritization
    - TimeScope – used to change the "Future Year"
    - Allocator – allocate areas for tree planting based on suitability score (see below)
    - Reports -

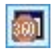


(2) Getting Started

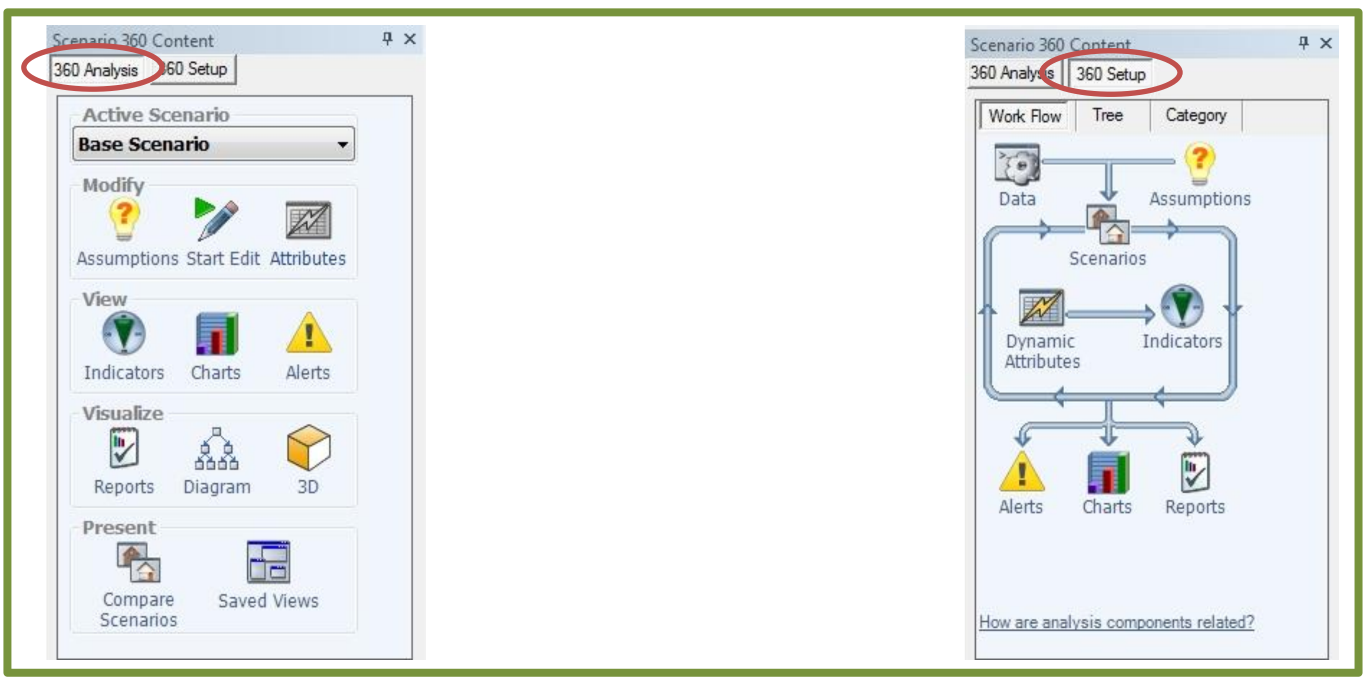
The following general tips are offered for getting started with CV:

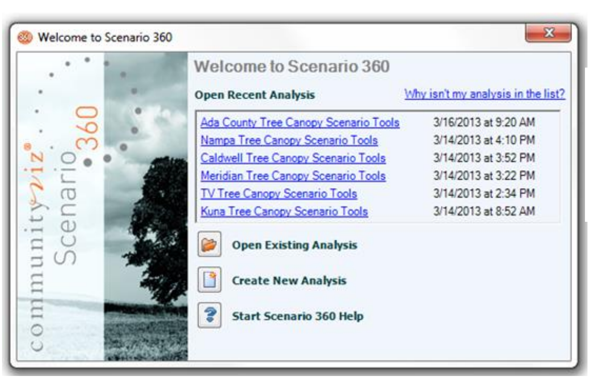
- Files and folder structure
  - A "CV Analysis" folder contains several standard sub-folders, a geodatabase that includes all "dynamic" layers (see definition below), and an ArcMap .mxd project.
  - The entire folder "<NAME> Tree Canopy Scenario Tools" needs to be copied to a folder on the local C: drive, preferably "C:\CVFiles". Note that this directory is created when CommunityViz Scenario 360 is installed and is recommended.
- Opening and Saving a CV Analysis (see example on next page below in this section)
  - **Do not use ArcMap 'Open' to open the .mxd.** Instead, use the red "Scenario 360"  icon in the Scenario 360 Toolbar and either browse to C:\CVFiles and into the analysis folder—or—open a recent analysis. A Scenario 360 project will look like this: 

  - Saving the .mxd can simply be done using the ArcMap save command.
- Editing Data in a CV Analysis
  - Begin/end editing either by using the Start Editing options in ArcMap, in CV under the Analysis tab (Content window), or by using the Scenario 360 toolbar Start Scenario Editing button .
  - All other editing and saving is done using ArcMap standard functions.
- Software Versions
  - The "TV CV" tools were created using version 4.3 of CommunityViz.
  - They will work in ArcMap 10.0 or 10.1 (the versions most widely used at time of project completion). An analysis can be "down-saved" from 10.1 to 10.0 through the following simple steps:
    - Open the v10.1 CV analysis in ArcMap using Scenario 360 as usual
    - Under "File", choose "Save as Copy" and select v10.0 from the dropdown. Name the copy with 100 in the name so it reads "CVAnalysis100.mxd. Close the .mxd and DO NOT save.
    - In ArcCatalog under the CV analysis folder in C:CVFiles, delete the .mxd without "100" in the name (the v10.1 map document) and then rename the .mxd with "100" in the name to the original "CVAnalysis.mxd."

- Navigating the Analysis
  - In the CV content window, which can be docked wherever convenient in ArcMap (see examples below), there are two main tabs: Setup and Analysis. Hint: if you don't see the CV Content Window, or accidently close it, you can re-open by click this button  on the Scenario 360 toolbar. The next page contains an image of the Content Window tabs.
  - "Setup" is used to create or change CV components such as Assumptions, Dynamic Attribute Formulas, Indicator formulas, Charts, Saved Views or Reports, described below. For example, to change the colors or decimal places in a chart or to change the range of possible values in an Assumption, use the Setup tab.
  - "Analysis" is used to change variables and run models and tools. For example, one can access the "slider bars" in CV under the Analysis tab in order to change assumption values like suitability factors, Average Tree Size, Future Year, etc., and see the impacts dynamically in charts.

CV Content Window with Analysis and Setup tabs followed by the Opening an Analysis window:





Opening a CommunityViz Analysis

(3) Regional-Scale Urban Forest Scenario Tools

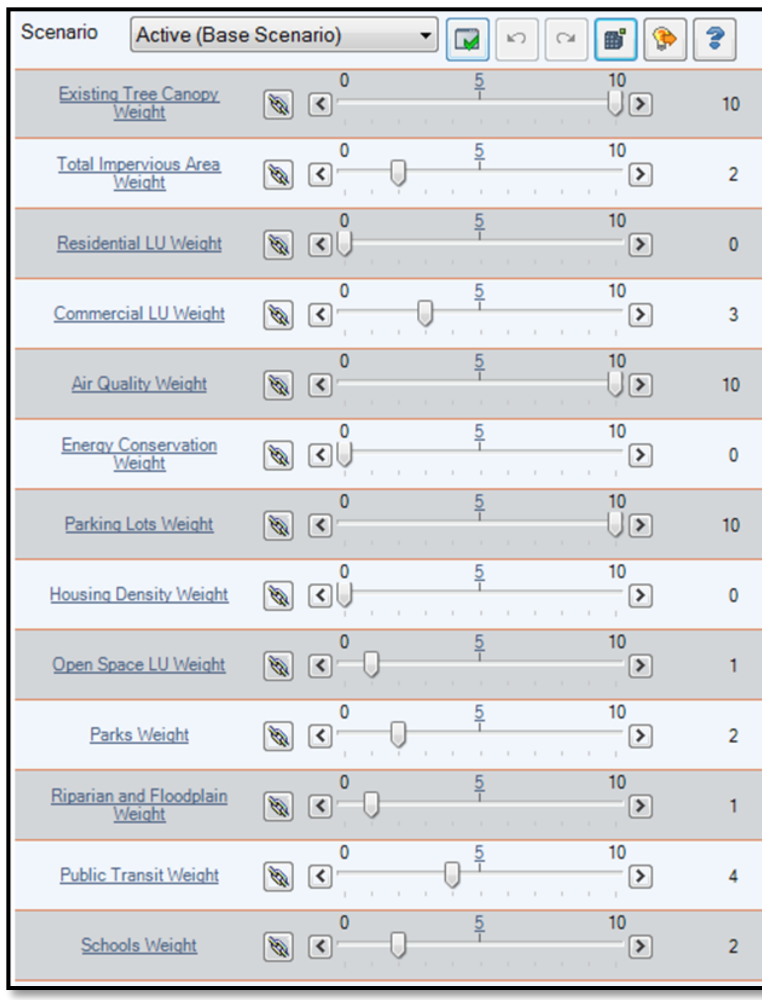
The CV tools include a set of regional-scale data layers and functions for bigger picture "what if" analysis of tree canopy and associated ecosystem service benefits. The components are described below. For site-level (individual tree) tools, skip to the next section.

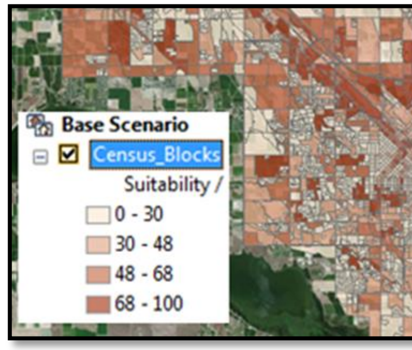
Tree Planting Prioritization using the CV "Suitability Wizard"

With tens of thousands of potential planting sites mapped per city in the Treasure Valley region (described in Appendix C), it is critical to prioritize areas where plantings are needed most and multiple benefits can be maximized. A GIS-based suitability model was created in CV for this purpose. Environmental, social and economic criteria (aka, factors) that influence strategic tree planting were incorporated into the census blocks and potential planting sites databases as GIS attributes. These attributes are numeric values either based on the land cover data (% of tree canopy, % of planting space, % of impervious area, etc.) or proximity relationships such as "true/false" (near a building Y/N, near a parking lot y/n) or other GIS analysis (amount planting space near buildings for energy conservation benefits).

Key Terms for Suitability:

- *Factors*: criteria included as attributes in the census block and planting sites databases. Examples include the amount of tree cover and planting area within the census block, and near the west sides of buildings for energy savings. Land use type, proximity to major arterials or neighborhood streets, riparian corridors, or large impervious surfaces areas are examples of other factors.
- *Weights*: using this system, important factors (criteria) can be weighted more heavily than others in the calculation of a census block's "suitability score" (defined below) by applying a value of 0 to 10 using CV Assumption "slider bars" (shown at right). A higher value gives greater weight to the score, while a lower value specifically de-emphasizes the importance of that factor.

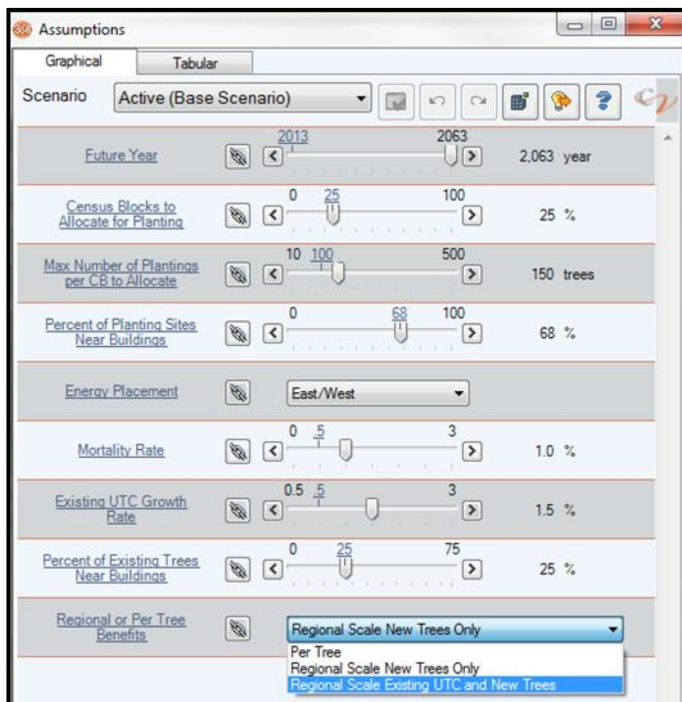




- *Suitability Score*: a value between 0 and 100 calculated for each CB or potential planting site based on weights applied to factors. Maps can then be made showing a thematic display of priority tree planting based on this suitability score value, e.g. green areas have a high score while red have a low score (see image below).

In the suitability model, existing tree canopy percent is a *numeric value* where a *lower* value equates to a *higher* planting priority. For most other factors (aka, criteria), the higher the numeric value the higher the suitability score. Examples include the % planting area within a census block or % of a census block that is impervious area, where the higher the %, the higher the score that block gets in the model.

Many factors relate to specific tree benefits. *For energy conservation*, a census block with a high percentage of planting area near residential buildings results in a high score. *For stormwater management*, if a census block is in close proximity to riparian areas and has a high number of potential planting locations within 50-feet of parking lots, then it can receives high score. *For air quality* (AQ), areas where trees can improve AQ were defined as being adjacent to highways, major streets, and parking lots. For true/false attributes like this, a ‘1’ is given to planting sites or census blocks that meet the condition (are within the distance) and a ‘0’ for ones that are not within the specified distance. A complete list of factors and the rule sets used for each is at the end of this document.



For land use types, a 0 vs. 1 approach was used for each type. If a potential planting site is on residential land use, the ‘Residential’ field value will be ‘1’. For census blocks, more than one land use field can have a ‘1’ in areas with greater mixed use. Using this approach, each land use type can be separately weighted over others (described below).

When factors are weighted from 0-10 using CV Assumption “slider bars,” a weighted suitability score between 0 and 100 is calculated for each census block, with CB’s near 100 being the most suitable for tree planting for a particular set of weighted priorities. Potential planting sites include a suitability score, but are not dynamic as are census blocks because of the sheer number of records would cause long calculation times.

Dynamic fields are recalculated after normalizing values based on the max and min value for each attribute (for example, a range of percentages of existing canopy cover or more simply a ’0’ vs. ‘1’). For a “1” given to a census blocks that met a condition, the normalized values are therefore 0 and 100. If the values are 0, 1 or 2, then the normalized values are 0, 50, and 100.

Factors (attributes) including suitability scores can be queried using GIS (without CommunityViz) to select, symbolize, or display census blocks and potential planting sites that meet certain criteria.

Suitability scores are the base unit of analysis for all of the urban forest scenario tools in this guide. What this means is all the tools presented here use the suitability score of census blocks as the main data input to show where to prioritize tree plantings. Before using any of the other tools (grow out tools, tree tracking tools, benefit tools), you should first run the suitability tool to make sure that the suitability scores these tools are using accurately reflect the scenario you are modeling.

CV “TimeScope and Allocation Wizards”

The TimeScope and Allocator wizards allocate trees to plant in CBs over time at a rate specified in the setup process. A time horizon of 50-years was used in the CV TimeScope wizard and applied to the census blocks layer. This model ties to suitability in that the more suitable a CB is for planting, the sooner it is “built” (planted) in the tools. This creates an Assumption slider bar called “Future Year.” As future year increases, potential planting sites within CBs are planted, age for trees in CBs is calculated, and this age is used to summarize the appropriate ecosystem benefit values from lookup tables.

The Allocation wizard provides a way to allocate trees in CBs over time based on suitability score and the total number of potential planting sites. Two slider bars are directly related to Allocation: (i) Max Number of Plantings per CB and (ii) Percent of CBs to Plant. Given not all planting sites in a CB will be planted, these Assumptions allow a user to reduce the number of trees planted in a future grow-out scenario.

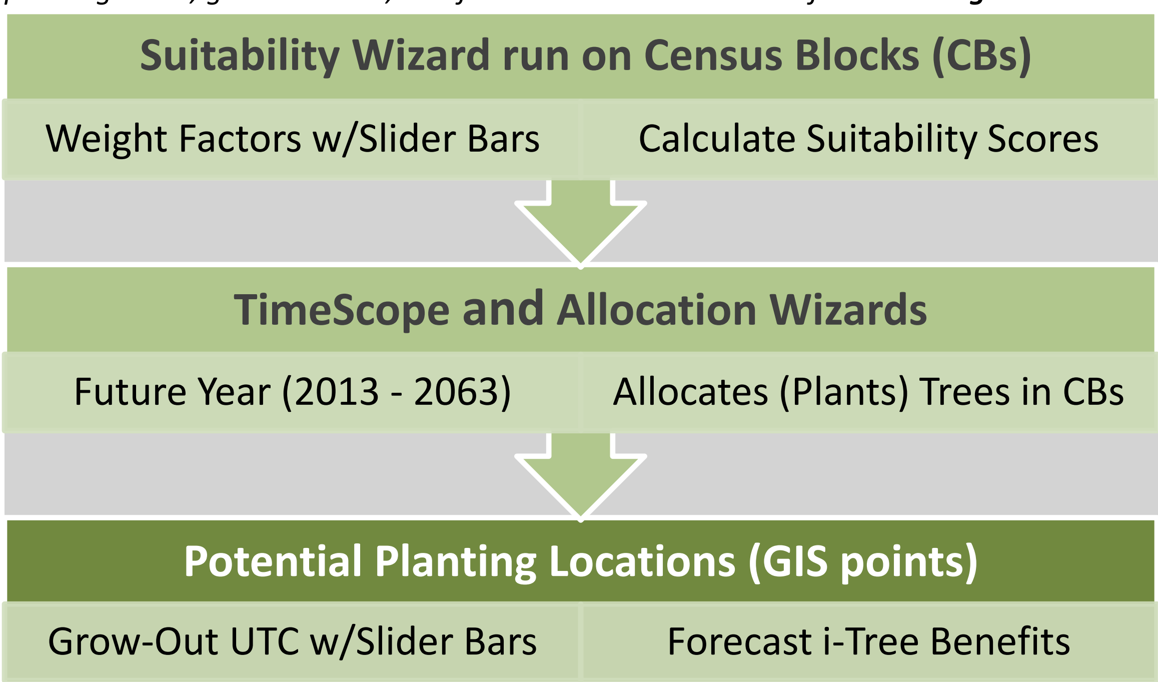
Other Regional-Scale Tools Information

The Assumption “Per Tree or Regional Scale Benefits” allows a user to show tree benefit values in charts for site-specific individual trees (described in the next section) vs. at the regional level. For the regional scale, there are two options. Selecting “Regional Scale New Trees Only” will force CV Charts to only show tree and benefit totals for new “future” trees, while “Regional Scale Existing UTC and New Trees” will show benefits of newly planted future trees as well as the existing tree population. The latter will show much larger results and is based on 2.4M trees regionally (prorated for cities based on size), as estimated from the i-Tree Eco inventory sample plots. Both show *cumulative* tree benefits over time to the future year selected by the user, not *annual* benefits.

Regional-scale tree benefits are based on the average value for the 12 common species selected for the Treasure Valley and modeled in i-Tree over a 50-year period. The existing tree population is also multiplied by the average benefit types by age. Based on tree structure metrics from the i-Eco sample, the model assumes 51% of existing trees are young (0-6" diameter at breast height, or DBH), 32% are mid-age (6-12" DBH), and 17% are mature (>12" DBH). To "localize" the tools and values for each CV Analysis at the city-level, the following assumptions were incorporated into the tools for the existing tree population.

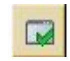
- The Assumption "Tree Population" was reduced from 2.4M trees regionally to each city based on square mileage, e.g. if a city was 25% of the total acres of the study area, it received 25% of the 2.4M trees.
- Existing trees in Boise, Eagle, and Garden City were assumed to be 33 'Young', 33% 'Mid-Aged', and 33% 'Mature', whereas the other cities were given 70-20-10 (Young-Mid-Mature). This can be changed easily by the user under Setup, Assumptions.

This schematic provides a high-level illustration of the CV analysis components to prioritize tree planting areas, grow-out UTC, and forecast tree scenario benefits at the ***regional-scale****.*



Steps for Using the Suitability (aka, Prioritization) Model

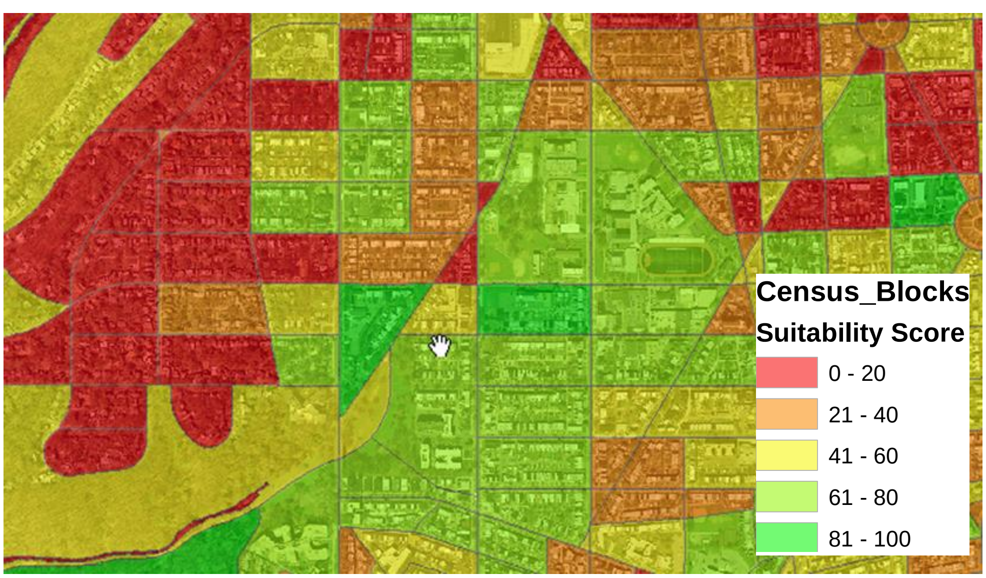
1.) Open one of the Saved Views that was setup specifically for Suitability. Note there are two options; one allows for weighting all 19 factors (aka, criteria) in the model while the other only uses the most common or most significant factors. Go to: CommunityViz Analysis Tab >> Saved Views >> and double click the View you want.

2.) In Assumptions, choose a weight between 0-10 for each factor and click "Apply"  to recalculate suitability scores for every census block based on the chosen weights. *Remember that even if a slider bar for a factor is turned off, the weight last set for that factor is still influencing the model and suitability score.*

3.) Under ArcMap layer symbology, determine the value ranges and colors to display the Suitability Scores field. The example below shows five "equal interval" classes but that may not always be useful in visualizing the distribution of scores. In some cases, the majority of census blocks may fall between low, middle, or high ranges based on weights.

4.) At this time, you may want to adjust other Assumption sliders to see the impact of tree size, mortality, and planting volume on changes in canopy cover or tree canopy benefits (open additional CV Charts as needed).

5.) To see only the census blocks that were "planted" based on your model inputs, use ArcMap's "Definition Query" tool under Layer Properties and type "Allocated > 1." This will show the areas that have been planted because they have a high suitability score and will therefore impact Chart summaries.



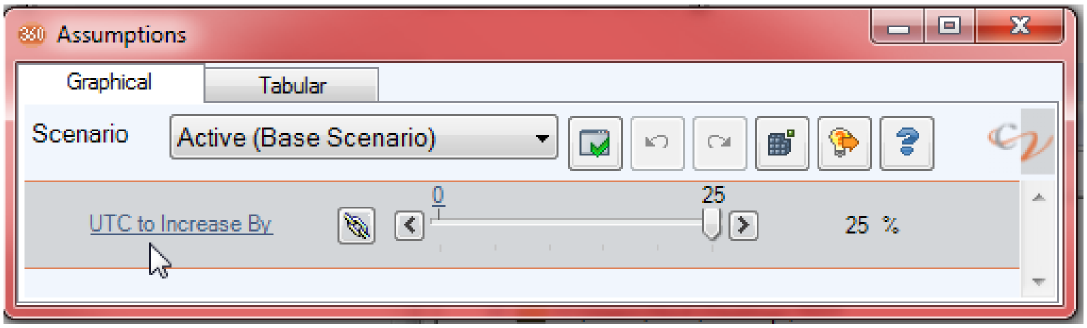
An example result from running the suitability wizard for census blocks. Blocks with a higher score (green) are better suited for new plantings based on weights entered in the Assumption sliders. Tree planting in these areas will meet multiple criteria, in particular factors with weights

Simple UTC Grow-Out Tool

This Assumption slider allows a user to do simply "what if?" test. A user can add 5, 10, 15, or 20 percent tree cover to "select" census blocks. Select census blocks are those with at least 1% but less than 25% existing tree cover. This helps users to visualize the amount of canopy that could possibly exist in the future if new and existing trees grow in areas with a high need.

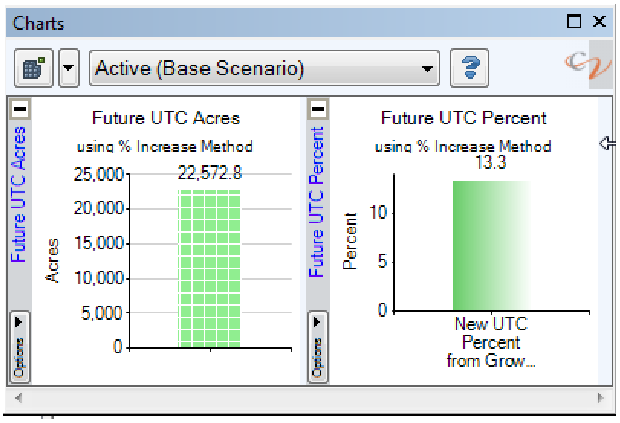
Steps for Using the Simple UTC Grow-Out Tool

1. If desired, run Suitability (described above) to create new scores for each census block. Note though that unlike above, in this tool tree canopy is not grown-out according to suitability scores where blocks with the highest scores get "planted" first. This slider bar simply adds the percent canopy chosen in the tool to the existing UTC percent.
2. Open the Saved View named "Simple UTC Grow-Out Tool" to pull up all the layers and slider bars associated with this tool. CommunityViz Analysis Tab >> Saved Views >> double click Simple UTC Grow-Out Tool.
3. Set the slider bar "UTC to Increase By" to 5, 10, 15, or 20% and then click the green check button to apply this setting a recalculate results.
4. You can now view census blocks color-coded by their theoretical future UTC percent in the map. Two charts will update to show the new, theoretical UTC percent for the entire city



based on the canopy grow-out and the estimated number of trees that need to be planted in the select census blocks to achieve the theoretical canopy increase.

Census blocks with 0% canopy or greater than 25% canopy will not change unless the attribute formula is modified.



Advanced UTC Grow Out Tool

This sophisticated canopy grow-out model allows a user to manipulate several in-depth parameters to create "What If?" canopy scenarios. Assumption sliders in this tool are:

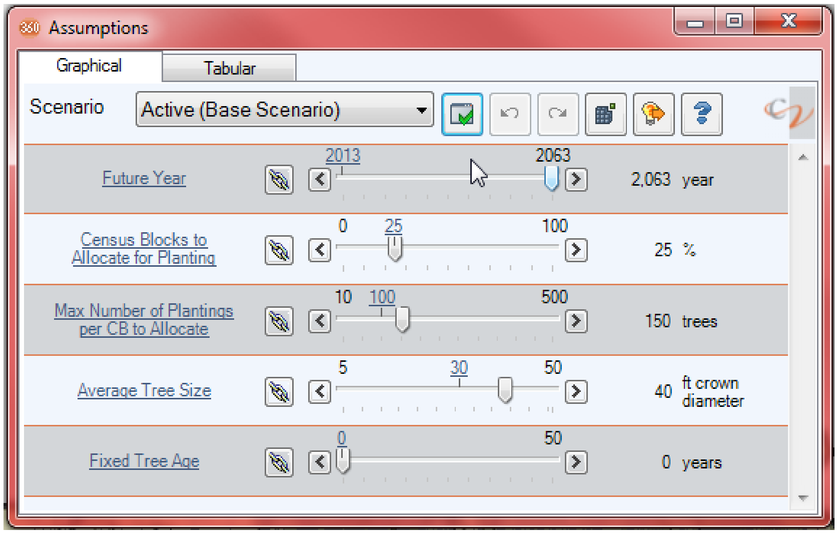
- Average tree size
- Percent of census blocks (CBs) in which to plant
- Maximum # of trees to plant in each CB
- Future year
- Fixed tree age

Results of this tool are driven by suitability scores[4] meaning that census blocks with a high score are "planted" and grown-out first. This model updates tree age over time which impacts cumulative (lifetime) benefit totals. Tree size impacts future UTC acres and percent, per CB and at the regional or citywide scale. Users include anyone interested in adjusting multiple parameters to forecast future UTC and benefits in the region or their city.

Steps for Using the Advanced UTC Grow-Out Tool

1. First, use the suitability model (described above) to create new suitability scores for each census block reflecting the scenario you are interested in. This is important because trees in this tool are grown-out according to suitability scores (blocks with the highest scores get "planted" first).

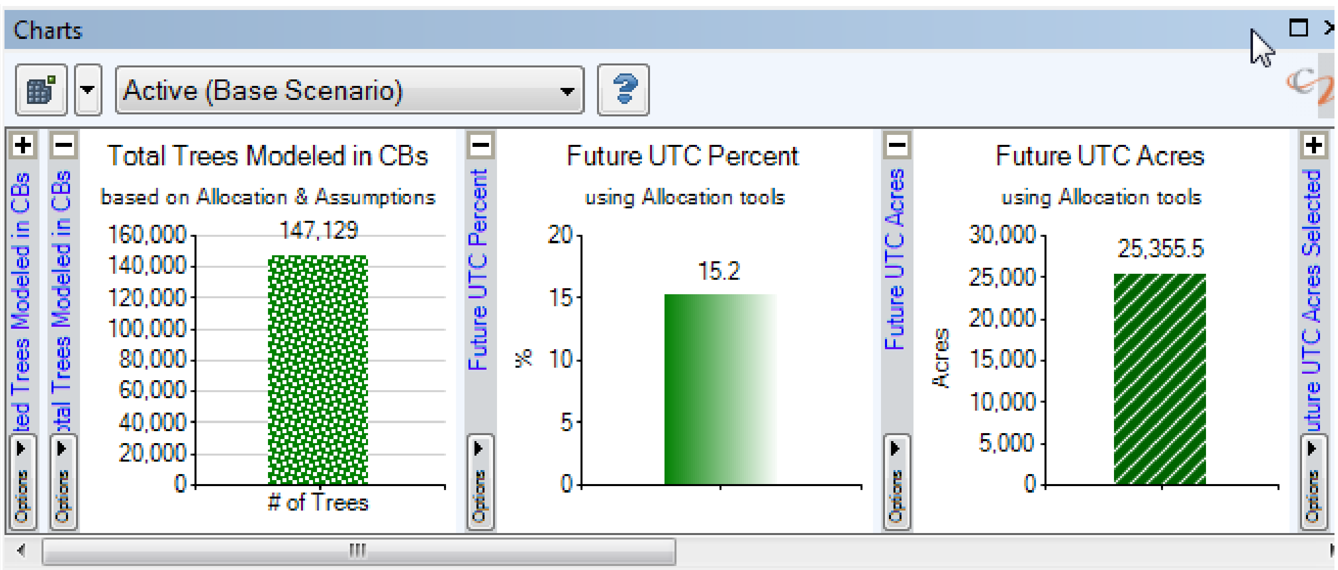
2. Now, open the Saved View named "Advanced UTC Grow-Out from Allocation Tools" to pull up the layers, charts and slider bars associated with this tool. CommunityViz Analysis Tab >> Saved Views >> double click Advanced UTC Grow-Out From Allocation Tools.



Using the slider bars seen here,

[4] Suitability simply means that the model scores census blocks based on how well they meet the conditions (called assumptions in CommunityViz) the user selects. Additional user criteria (assumptions)—such as what percent of all census blocks do you want to add trees within, a cap on the maximum trees to be added to any census block—will focus on those census blocks which best meet the user defined criteria.

3. adjust the year, number of census blocks and amount of potential planting sites to model, growth and mortality rates, and choose to model individual trees or regional canopy cover benefits.
4. Click the green check button to apply this setting and recalculate results.
5. You can now view census blocks symbolized by their new, theoretical UTC percentage in the map. Three charts will also show you the new, theoretical UTC acres and percent for the entire city based on the canopy additions and the estimated number of trees that need to be planted to make the theoretical canopy increase a reality.
    a. *Note that tree benefit summary charts will update through formulas in the background but are not shown with this Saved View. At any time the benefit charts can be opened from the Scenario 360 Analysis tab or through Saved Views for specific ecosystem services analysis. See sections 6 and 7 below.*



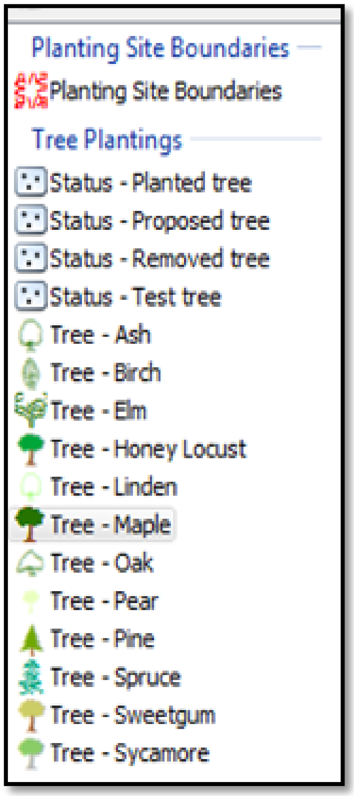
Using the Fixed Tree Age slider bar: This Assumption slider allows you to force all future tree plantings to be based on the same fixed age. This overrides the age created from the allocation wizard and the Future Year slider bar. As an example, to model tree plantings in a park or downtown district as being planted at the same time instead of staggered over time based on allocation and suitability score, set this slider to the age you wish to model. It will apply to the count (number) of planting sites in census blocks (all or selected ones). CV's "IsSelected" formula is described further below and can be a useful addition to this tool to only forecast trees in census blocks that are selected using ArcMap tools. If you do not want a fixed age, leave this slider at zero (0) to allocate trees planted in census blocks over time. When finished using this tool, remember to set Fixed Tree Age back to zero (0).

(4) Site-Level Tree Planting, Tracking, and Cost/Benefit Analysis Tools

Each CV analysis includes a "Tree Plantings" and "Planting Site Boundaries" layer. These allow a user to draw a site boundary such as a neighborhood, property, school, park, corridor, or other planting event to track trees and their cost/benefits. After drawing the perimeter of a site, a user is prompted to name the site, select a category, and enter several types of average tree costs, as shown below. Specific steps to map new planting site boundaries and tree plantings are provided here. These tools can be used for tree inventory and educational demonstrations.

Steps for Using the Site-Level Tree Inventory Tool

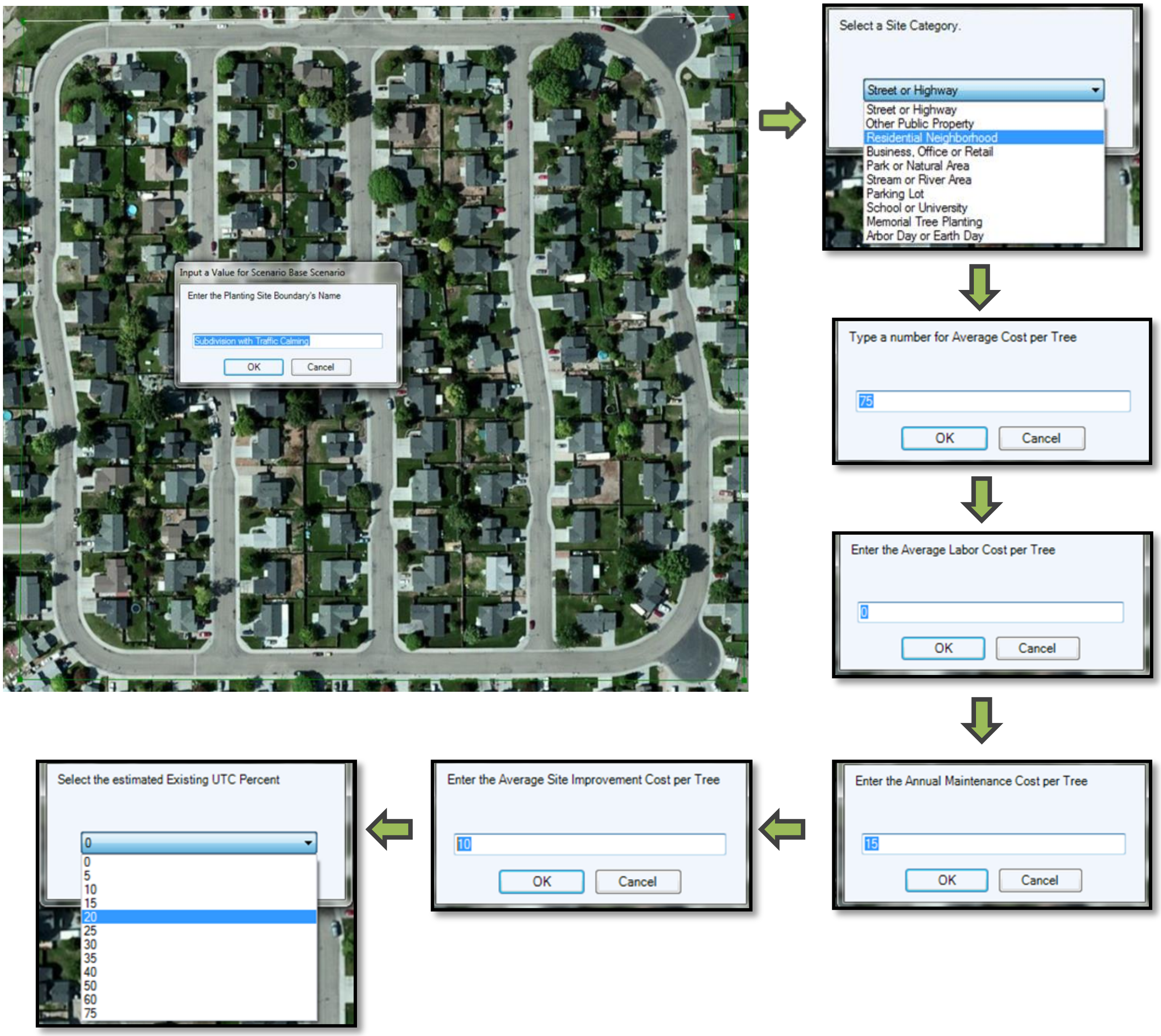
Step 1: Adding a Planting Site Boundary



a) *Open the Saved View named "Add Trees and Planting Site Boundaries".* CommunityViz Analysis Tab >> Saved Views >> double click *Add Trees and Planting Site Boundaries.*
b) *Begin an edit session using either ArcMap or CV tools and select the Planting Site Boundary layer, seen in the ArcMap feature templates window at top right. Note the Tree - Genus features allow you to select tree types to add to a planting site boundary and the CV "Styles" allow you to change attributes of trees you've already added, described below under "CV Styles".*
c) *With the Planting Site Boundaries layer selected, use ArcMap construction tools to draw a polygon boundary of the planting area.*
d) *You will be prompted to answer the following questions:*
    a. *Enter a name for the planting boundary*
    b. *Select a site category from the drop down menu*
    c. *Enter an average purchase cost per tree*
    d. *Enter an average installation cost per tree*
    e. *Enter an average annual cost for maintenance*
    f. *Enter an average cost per tree for site preparation*
    g. *Select estimated existing tree canopy percentage for the site*

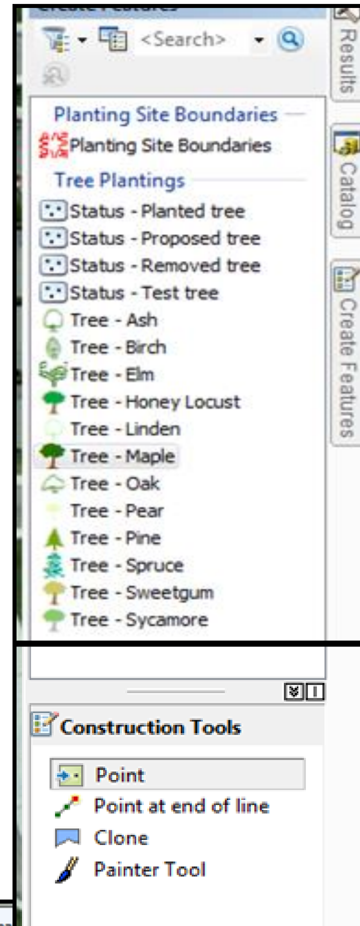
See diagram on next page:

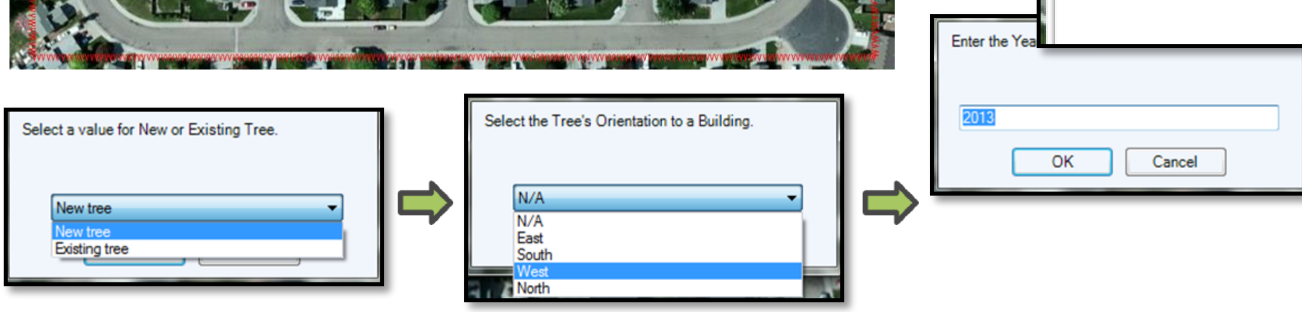
Diagram of the process of mapping a planting site boundary and the prompts that are asked each time.

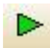


Step 2: Adding a New or Existing Trees

After the site boundary has been delineated, named, categorized, and average costs entered, trees can be added to the site. Information is tied together between the planting site boundaries and the tree points *dynamically*. The prompts that appear when adding trees can be seen in the dialogues below. Note that trees can also be added without (outside of) a site boundary if desired and separate prompts will appear for those sites to capture cost information (not shown below). Addition prompts can be added by creating new dynamic attribute formulas in the Tree Plantings layer using the CV formula wizard and “user choice” type attributes.

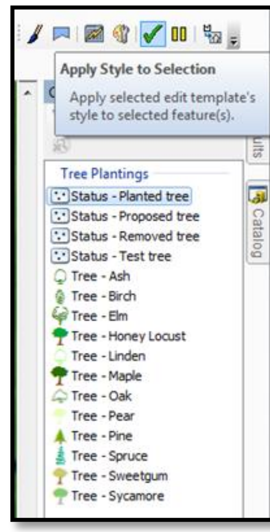




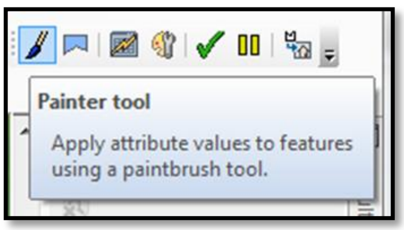
When adding trees, several formulas are dynamically performed, for example, the land use type from the underlying parcels layer is used to join the land use type to the tree point. Some of these calculations can be "paused" using the "Suspend Dynamic Updates" button on the Scenario 360 Sketch Tools tool bar,  , to add trees faster and have calculations perform all at once after. When ready to do this, click the button again, which will now look like this: 

Additional Related Tools

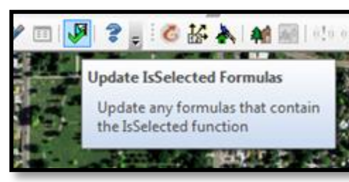
Painting Tree Attributes using CV "Styles"



In the feature templates list shown at right, CV "Styles" can be used to "paint" features (trees) with text or numeric attribute values such as a Tree Species or its Status type. To apply a CV Style, select the tree record(s) for which you want to change attributes in the map so that the feature is highlighted, click on the CV Style (a tree species or a "Status" type), then use the Painter brush tool or "Apply Style to Selection" tool (seen at right and left). The attributes for the selected records will update along with any changes to CV Charts.

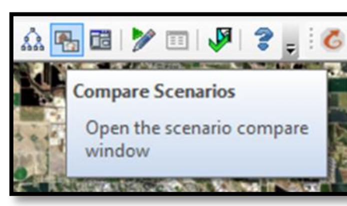


Showing Results for "Selected" Features Only



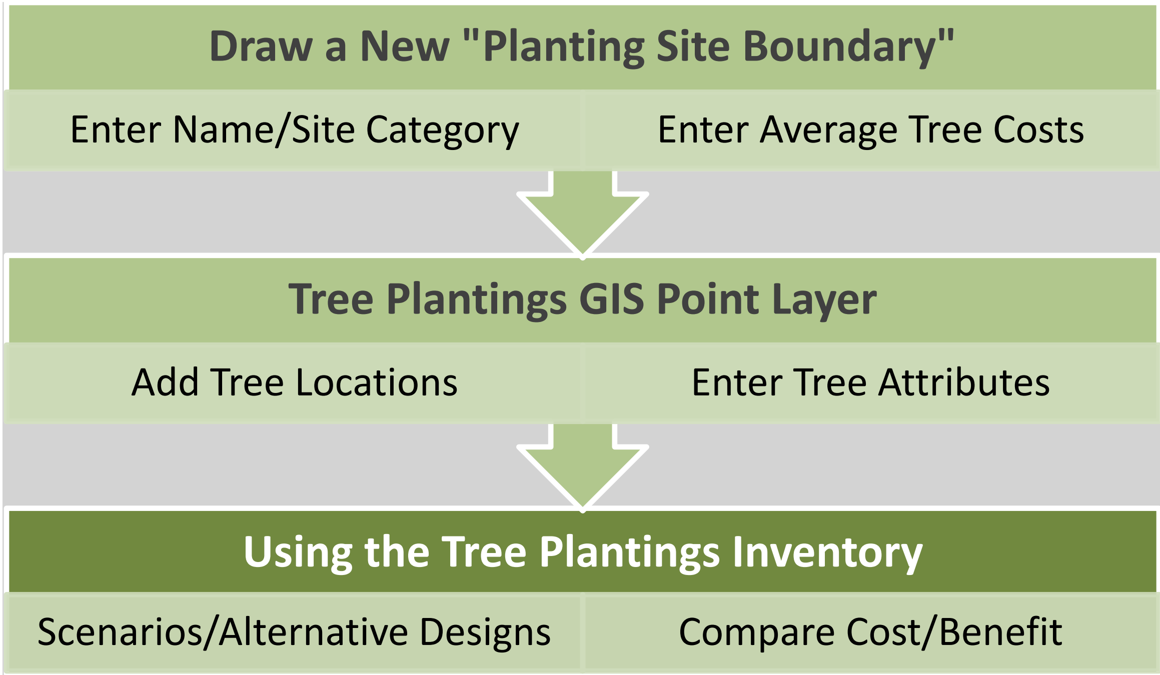
By using ArcMap selection tools and CV's "Update IsSelected Formulas" tool (seen at right), Charts associated with Tree Plantings will only show summaries for the *selected* records. This can be used to show the costs, benefits, and tree count for a particular species or geographic area.

Comparing Scenarios



The site-level CV tools can be used to compare two alternative design scenarios side-by-side. CV's "Compare Scenarios" function (seen at right) has many chart and map display options. A new Scenario in CV must be created first.

*This schematic provides a high-level illustration of the CV analysis components available to plant and track trees, add costs, and forecast tree benefits at the **site-level scale**.*



(6) Ecosystem Services Analysis Tools (Air Quality, Energy Conservation, and Stormwater)

Modeling environmental and economic benefits of urban trees in the Treasure Valley is a key task for this assessment. Tools integrating three ecosystem benefit types were developed in CommunityViz using i-Tree Eco software to help resource managers identify locations for planting that will maximize specific benefits and forecast canopy and these benefit types into the future. The three benefits focused within the tools are:

- Air Quality
- Energy Conservation
- Stormwater Mitigation

The three benefit tools are very similar in functionality. They are based on the Advanced UTC Grow-Out Tool and a Saved View for each includes all of the components of that tool. Each benefit tool and its associated Saved View also include custom Assumption sliders bars that relate to and support analysis of the benefit of interest. For example, the Saved View for Energy Conservation includes three slider bar Assumptions to adjust the potential benefits of tree canopy on energy demand over time.

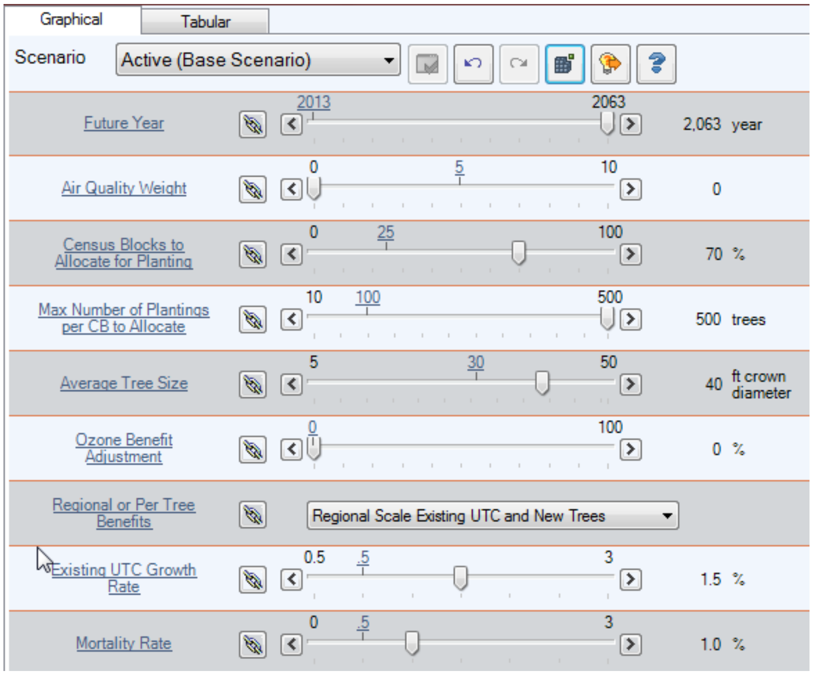
These tools produce several types of results that are dynamically updated in both GIS layers (census blocks) and CV Charts. First, these tools utilize the Suitability Model and the weighting of factors (described above) to compute suitability scores for census blocks based on the benefit type of interest (air quality, energy conservation, and stormwater management). Secondly, these views forecast the desired benefit into the future in CV charts based on the number of trees planted, mortality, and other custom parameters. Lastly, these tools update other charts showing the total number of trees modeled and the future canopy cover created from the scenario.

Note that for each Saved View presented here, the first recommended step is to rerun the Suitability Model using weighting values appropriate to each ecosystem service (benefit) type.

Air Quality Benefit Tool

The air quality benefit tool is designed to aid users who are interested in finding areas to prioritize tree plantings where they will have the greatest impact on improving air quality. Specifically, these areas are along major roads and near parking lots. The air quality parameters unique in this tool are the Air Quality weighting factor (from the suitability model) and an Ozone Benefit Adjustment that allows a user to increase the amount of ozone removal benefit by trees in areas where concentrations are assumed to be highest and benefits will be greatest.

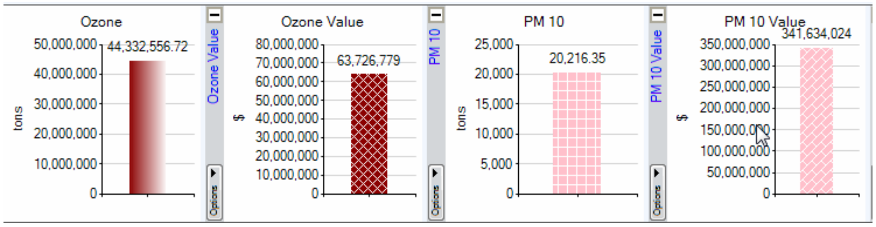
1. First, open a Saved View for Suitability and rerun the suitability wizard (described above) to create new suitability scores for each census block reflecting the benefits of interest. This is important because trees are planted in census blocks where suitability scores are highest and Assumption values used in a prior modeling scenario will not change when opening a new Saved View.

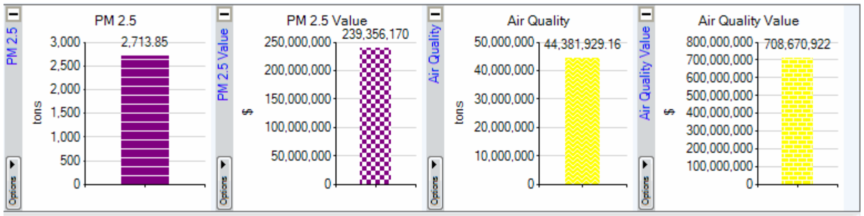


2. Now, open the Saved View named Air Quality: CommunityViz Analysis Tab >> Saved Views >> double click Air Quality.

3. Adjust the year, number of census blocks and amount of potential planting sites to model, growth and mortality rates, and choose to model individual trees or regional canopy cover benefits.

4. Adjust the specific slider bars related to air quality:





   a. The Air Quality weight adjusts how important tree planting is along major roads and near parking lots in each census block for creating suitability score.

   b. Ozone Benefit Adjustment allows the users to make an assumption on the increased ozone (O3) value of trees near parking lots, streets, and highways. The default is set to 0. Selecting 5 will multiple the total cumulative (lifetime) ozone mitigation benefit by 5%.

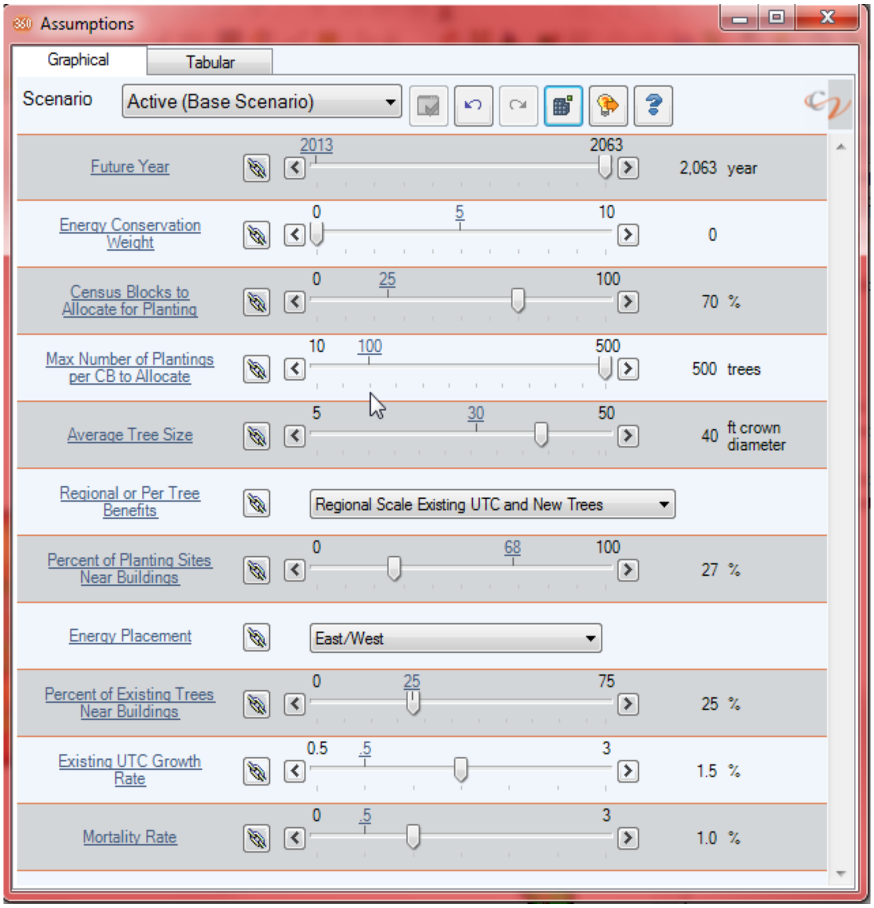
Click the green check button to rerun the models and see the updated results.

Energy Conservation Benefit Tool

The energy conservation benefit tool is designed to aid users who wish to prioritize tree plantings in areas that will maximize energy savings in residential homes. The unique energy conservation parameters in this tool are; assumptions about the percent of existing trees and potential planting sites that are within 50 feet of a residential building, assumptions about the placement of potential new plantings around homes, and the energy conservation weighting factor (from the suitability model).

Steps for Using the Energy Conservation Benefit Tool

1. Rerun the suitability wizard (described above) to create new suitability scores for each census block reflecting the scenario you are interested in. This is important because trees in this tool are grown-out according to suitability scores (blocks with the highest scores get "planted" first) and Assumption values used in a prior modeling scenario will not change when opening a new Saved View.
2. Now, open the Saved View named Energy Conservation: CommunityViz Analysis Tab >> Saved Views >> double click Energy Conservation.
3. Adjust the year, number of census blocks and amount of potential planting sites to model, growth and mortality rates, and choose to model individual trees or regional canopy cover benefits.
4. Adjust the specific sliders related to energy conservation:
    a. The Energy Conservation weight is part of the Suitability Model. It gives higher priority to census blocks with greater amount of space for tree planting near residential buildings



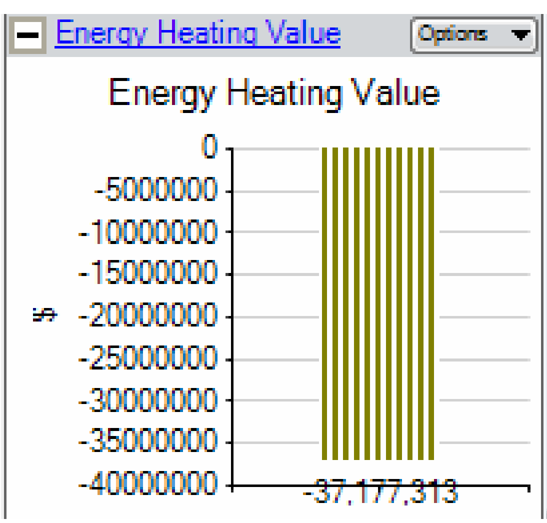
when calculating suitability scores. Planting space for energy conservation was defined as grass and open area within 50 feet of the west, northwest, and southwest sides of residential homes, summarized per census block.

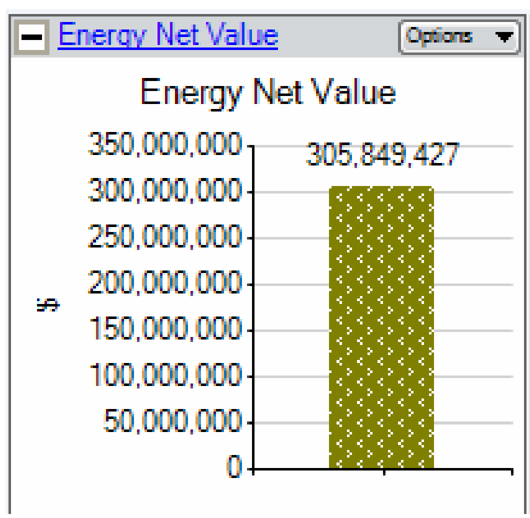
b. Adjust the “Percent of Planting Sites Near Buildings” slider bar to change the percent of potential planting sites that near residential homes. For a default value to consider, GIS analysis revealed that 52% of all potential planting sites across the Treasure Valley are within 50-feet of residential buildings. Given this will change in each community based on land use and existing tree canopy cover, users should adjust the slider based on local assumptions.

c. Adjust the “Percent of Existing Trees Near Buildings” slider bar to change the assumed percent of *existing* trees near residential buildings. This impacts the proportion of existing trees per city from the 2011 i-Tree Eco inventory in which energy related benefits are applied to. For example, you may want to assume that 50% of existing trees have an impact on energy savings based on local land use data and your city’s UTC results for residential properties. The default is conservatively set to 25% with a max of 75%. Note this only applies when the slider bar “Regional or Per Tree Benefits” is set to “Regional Scale Existing UTC and New Trees”.

d. Adjust the “Energy Placement” slider bar to model the impact of the orientation of new tree plantings around homes on energy conservation. Users can choose to assume that new plantings will be evenly placed around homes (choose “Averaged N/S/E/W”) or that plantings will be provide maximum energy saving benefits on the east and west sides of a home (choose “East/West).

Click the green check button to rerun the models and see the updated results.



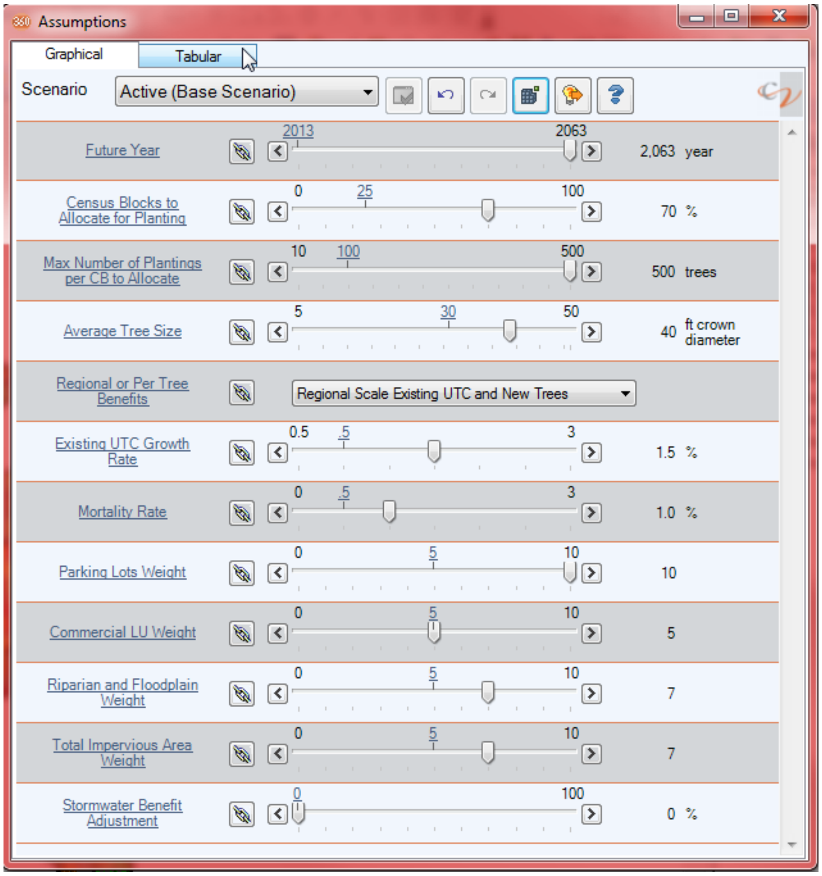


Stormwater Mitigation Benefit Tool

The stormwater mitigation benefit tool is designed to prioritize and see the effects of tree planting in areas that will maximize stormwater runoff mitigation and improve water quality. These areas are defined as: (i) near parking lots, (ii) near all impervious surfaces, (iii) near riparian areas or in 100-year floodplains, or (iv) on commercial land use. The specific stormwater parameters in this tool are four weighting factors from the suitability model and a stormwater benefit adjustment, described below in step by step instructions.

Steps for Using the Stormwater Mitigation Benefit Tool

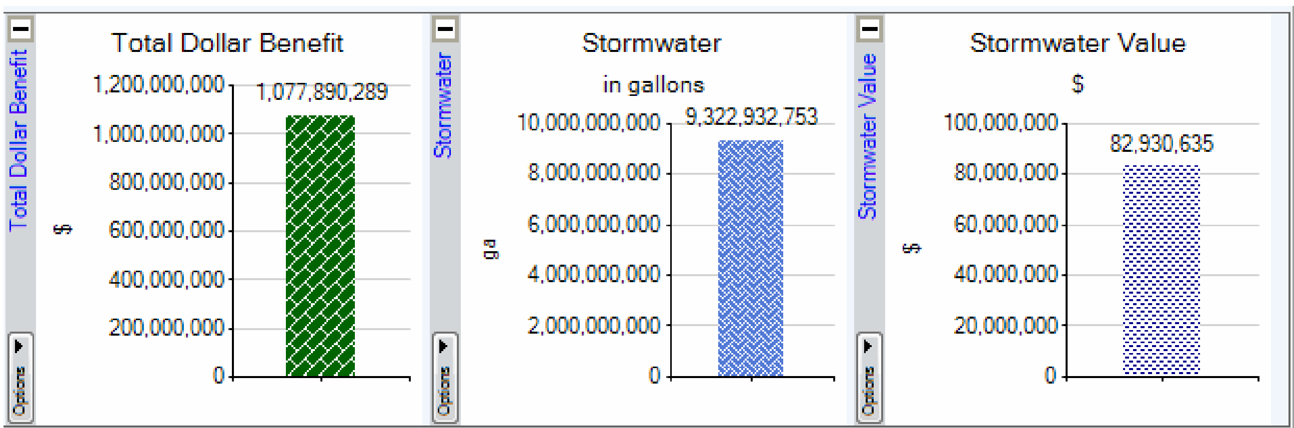
1. Rerun the suitability wizard (described above) to update suitability scores for each census block reflecting the scenario of interest. This is important because trees in this tool are grown-out according to suitability scores (blocks with the highest scores get "planted" first) and Assumption values used in a prior modeling scenario will not change when opening a new Saved View.
2. Open the Saved View named Stormwater Mitigation: CommunityViz Analysis Tab >> Saved Views >> double click Stormwater Mitigation.
3. Adjust the year, number of census blocks and amount of potential planting sites to model, growth and mortality rates, and choose to model individual trees or regional canopy cover benefits.
4. Adjust the specific slider bars related to trees and stormwater management:
    a. The slider bar weights shown here that are part of the Suitability Model are Parking Lots, Commercial LU (Land Use), Riparian and Floodplain, and Total Impervious Area. Adjust each of these to



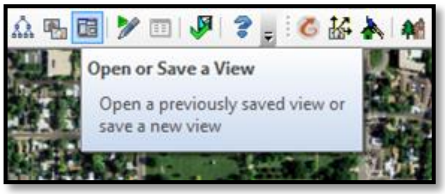
give a higher priority to census blocks that meet these conditions to update suitability scores. For example, apply a weight of 10 to Parking Lots to prioritize areas with a greater amount of space for tree planting near parking lots, defined as grass and open area within 50 feet parking lots summarized per census block, and use lower values to weight other suitability factors. To prioritize natural areas along streams, weight the Riparian and Floodplain factor highest.

b. Modify the "Stormwater Benefit Adjustment slider bar to increase the stormwater benefit value of future trees that overhang impervious surfaces. The default is set to 0. Selecting 5 will multiple the total cumulative stormwater benefit by 5%. This can be used over time to adjust benefit values as new research data becomes available on stormwater benefit of urban trees based on proximity to different types of impervious surfaces.

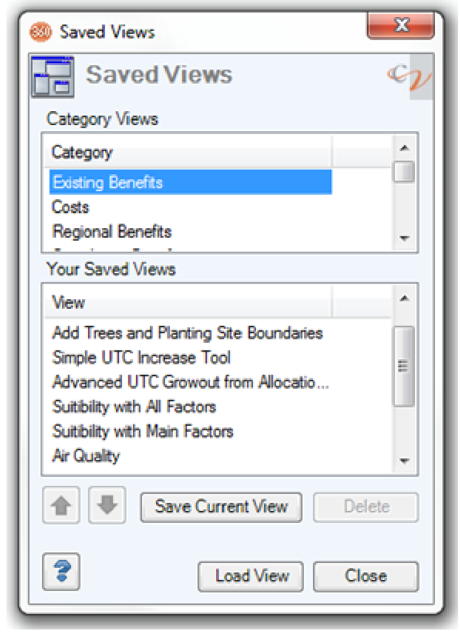
5. Click the green check button to rerun the models and see the updated results.



(6) Saved Views



In the main CV toolbar is an icon (seen at left) called "Saved Views." Similar to a Bookmark in ArcMap, this feature saves the spatial extent (scale) but additionally it opens the associated Charts, Assumptions (sliders bars), and loads the saved symbology for data layers. The benefit to the user is that only specific tools are shown for various uses, reducing the time required to open and customize numerous components of a CV analysis.



Several saved views were created for the TV regional UTC analysis at the site-specific scale (called "Per Tree") and regional (i.e., citywide) scale. Regional-scale charts can show results from either new trees only (Assumption "Regional Scale New Trees Only") or new trees *plus* the existing canopy cover as it grows over time (Assumption "Regional Scale Existing UTC and New Trees"). Generally, the saved views fall into three categories or functional themes: (i) based GIS data, (ii) tree canopy scenario tools, and (iii) tree benefit tools. Each saved view is described below beginning with the simplest to the most complex.

Saved View Name	Layers	Assumptions	Charts
UTC Assessment Results	Census blocks, planting sites, cities, Project area/Area of Interest (AOI)	None	None
Description/Intended Use: Show census blocks symbolized by their % Existing UTC. Users include anyone interested in seeing canopy cover across the region or in their city.			
Simple UTC Increase Tool	Census blocks, AOI or city boundary	% UTC to Increase by	Future UTC acres, Future UTC %
Description/Intended Use: This tool adds a user-defined % of canopy cover increase to census blocks with at least 1% UTC but no more than 25% UTC. Census blocks update dynamically as does the impact on total canopy cover (city or regionally). Users include anyone interested in seeing a general scenario of how canopy may change over time in areas with low canopy at the time of this analysis.			
Advanced UTC Grow Out from Allocation Tools	Census blocks (CB), AOI or city boundary	% of adjusted sites in which to add (allocate) trees , Maximum trees added per CB, Average Tree Size, Future Year, Fixed Tree Age	Future UTC Acres, or %, Future Acres or % Selected, Total Trees Modeled in CBs
Description/Intended Use: This sophisticated "what if" canopy grow-out model allows a user to change the average tree size, % of CBs in which to plant, maximum # of trees to plant in CBs, and future year. This is based on suitability[5] score (CBs with a high score are "planted" and grown out first). This model updates tree age over time which impacts benefit totals. Tree size impacts future UTC acres and percent, per CB and at the regional or citywide scale. Users include those interested in adjusting multiple parameters to forecast future UTC in the region or their city.			
Suitability with All Factors	Census blocks, potential plantings	All pertaining to suitability	None
Description/Intended Use: Allows users to use and "weight" any or all the various criteria available to calculate 'suitability scores' between 0-100 for CBs. This is a way to visually and spatially show those census blocks in which you may wish to target efforts based upon criteria on which you wish to focus.			
Suitability with Main Factors	Census blocks	% UTC, Parking Lots, AQ, Energy, PPA Vegetation	None
Description/Intended Use: Same as the previous saved view, but with fewer factors			

[5] Suitability simply means that the model scores census blocks based on how well they meet the conditions (called assumptions in CommunityViz) the user selects. Additional user criteria (assumptions)—such as what percent of all census blocks do you want to add trees within, a cap on the maximum trees to be added to any census block—will focus on those census blocks which best meet the user defined criteria.

Add Trees and Planting Site Boundaries	Tree Plantings, Planting Site Boundaries, Potential plantings	Future Year	Count of trees, cumulative costs, all benefit charts, average age of planting to grow out year
Description/Intended Use: This saved view is for calculating costs and benefits at a site-level scale. Users can define a planting site boundary, then add trees of 12 species/genus type, provide costs for site prep, tree purchase, planting and annual maintenance, grow out to a future year and have returned charts showing cumulative costs and benefits to that year. This can also be used for existing trees to calculate future benefits.			
Air Quality	Census blocks, potential plantings	Suitability (AQ, parking lots), Future Year, Ozone benefit adjustment	# of trees modeled, Total Air Quality, Ozone, PM10, PM2.5 ($'s and tons)
AQ Description/Intended Use: Prioritizes plantings for AQ benefits along highways and near parking lots; see impacts on air pollutants and dollar value of benefits from public health. Users include Idaho Dept. of Environmental Quality (DEQ), transportation planners, public health professionals, and community planning and development.			
Energy Conservation	Census blocks, potential plantings	Energy direction, Future Year, Percent of Plantings near Buildings	# of trees modeled, 4 energy charts ($'s and MWH)
Energy Description/Intended Use: Prioritizes plantings for energy benefits; see impacts on $'s and MWH's. Users include Idaho Power, sustainability planners, and anyone interested in reducing energy demand from trees.			
Stormwater Mitigation	Census blocks, potential plantings	Suitability (parking lots, riparian/floodplain, commercial, % total impervious), Future Year, Stormwater benefit adjustment	# of trees modeled, 2 stormwater charts ($'s and gallons)
SW Description/Intended Use: Prioritizes plantings near parking lots, riparian corridors, floodplains, commercial properties or ones with high impervious %; returns charts/results on the reduction of stormwater runoff. Users include stormwater managers, planners, and landscape designers.			

Limitations of Saved Views

There are limitations to the Saved Views function. Ones specific to the TV tools are described here.

1.) Symbology – the ArcMap symbol set such as a color ramp does not always work when reopening an analysis folder on a new machine, even within the same version of ArcMap. In this event, symbology will need to be reset by the user under the ArcMap Layer Properties, likely for census blocks which use three different color ramps in these tools (Existing UTC %, Future UTC Percent from Pct Increase Tool, and Suitability Score).

Assumption Values – the most recent slider bar values used during an analysis will carry over when a different Saved View is loaded. For example, suitability factor weights and "Per Tree vs. Regional Scale" sliders from one Saved View will be carried over when opening a new Saved View until Assumption values are changed. Additional factors related to suitability may need to

be added using the Organization Assumptions button (seen at left here) and in the case of site-level vs. regional benefits, the dropdown menu list will be need to be changed from ‘per tree’ to one of the regional options depending on the scale you desire to see benefits in charts for.

(7) Additional Information

CommunityViz planning software (http://placeways.com/communityviz/) is an extension for ArcGIS Desktop. Planners, resource managers, local and regional governments, and many others use CommunityViz to help them make decisions about development, land use, transportation, conservation and more. A GIS-based decision-support tool, CommunityViz "shows" you the implications of different plans and choices. Both flexible and robust, it supports scenario planning, sketch planning, 3-D visualization, suitability analysis, impact assessment, growth modeling and other popular techniques. Its many layers of functionality make it useful for a wide range of skill levels and applications.

A license includes three “seats” and several licenses were purchased by the Idaho Department of Lands for localities to facilitate use of the tools.

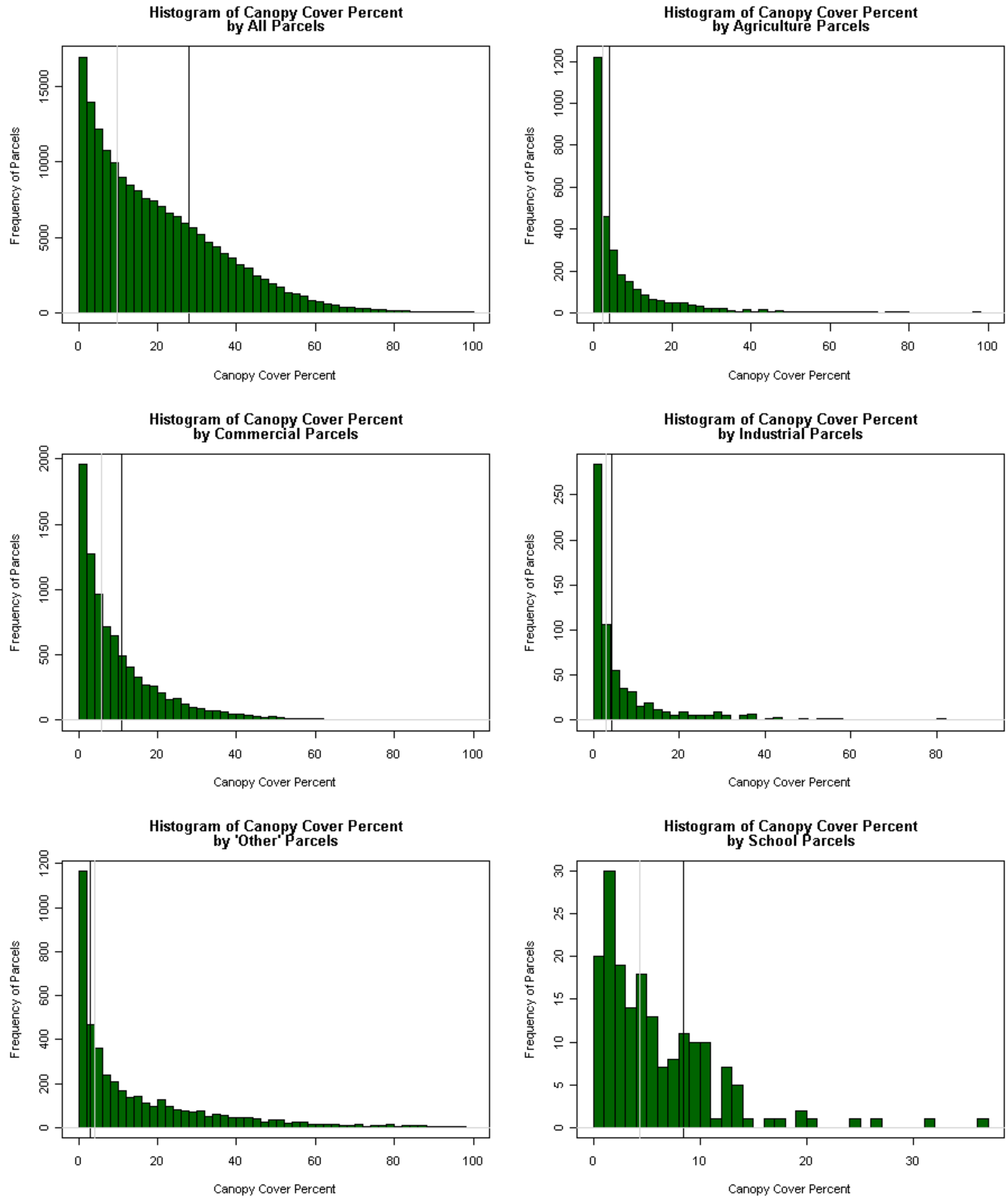
Placeways maintains an up-to-date and comprehensive searchable database online for help with CV components and terminology. Visit http://placeways.com/support/s360webhelp4-3/.

75^{th} Percentile Rule

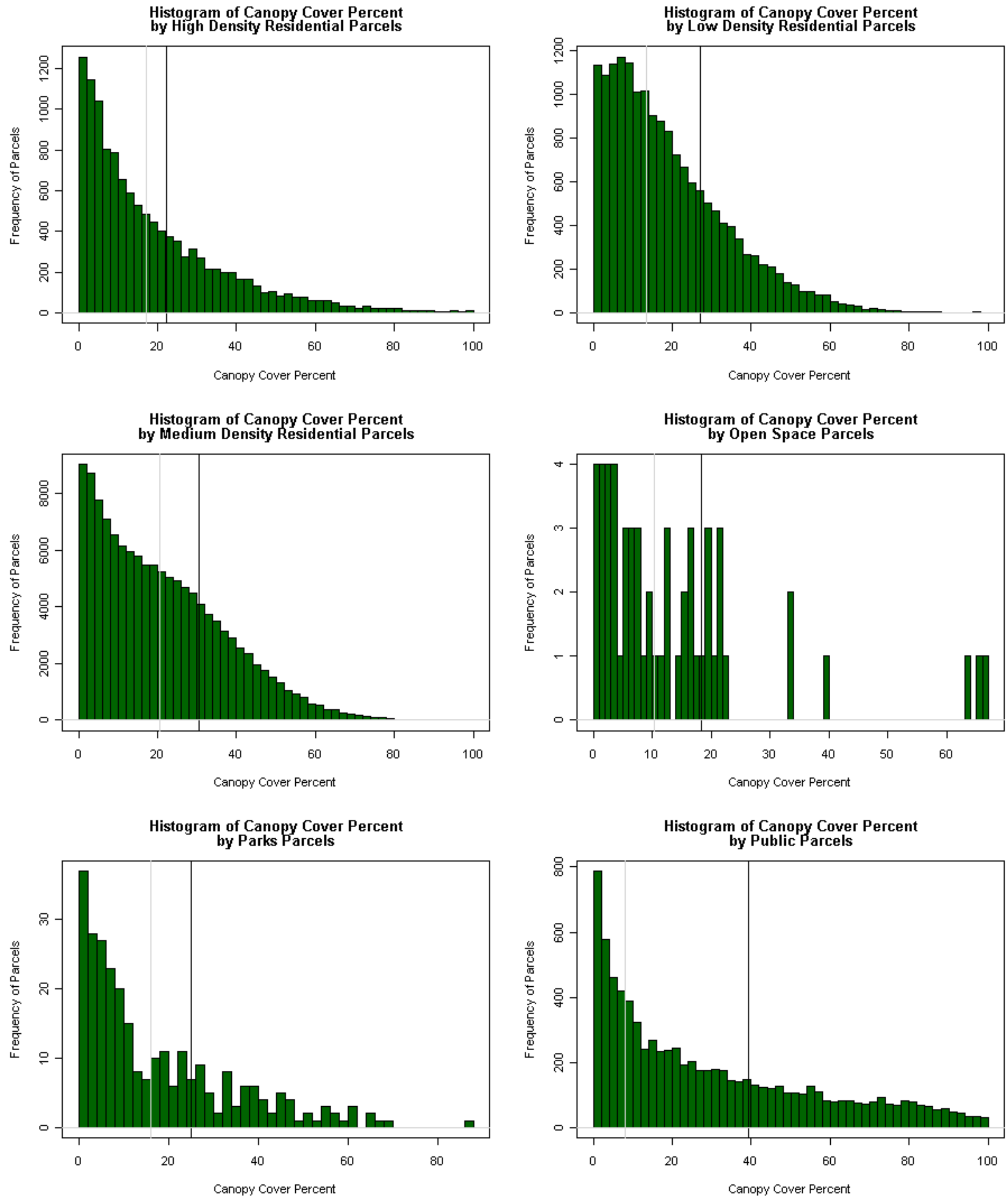
When the average current tree canopy percent (i.e. the 50th percentile) and the 75th percentile canopy percentages are similar to the additional percent required average (e.g. in the case of Opens Space, Parks, and Residential Medium Density land use types, see Table 13 on page 44), this indicates that canopy cover is fairly uniformly distributed across all parcels in that land use category. If values are lower than the additional percent required average (e.g. in the cases of Commercial, Other, Residential High Density, and School land use types) this indicates that a large number of parcels contain very low canopy percentages (data are skewed to the left side of the distribution). When the difference between the two values is large within a specific land use category (e.g. Industrial, Public, and Residential Low Density), this indicates that a large number of parcels within that land use category contain canopy cover percentages much greater than the average (values are skewed to the right side of the distribution).

Across all land uses and parcels in the Treasure Valley, the canopy cover percent at the 75^{th} percentile is 28%. This value indicates that 25% of all parcels in the Treasure Valley have a canopy cover percent of 28% or greater, and 75% of parcels have a canopy percent of 27.9% or less.

Further results can be interpreted from the tables on the following two pages and in the main body of the report. The average canopy cover percent across all land uses at the 75^{th} percentile is 17.9%. This value reflects the disparity between relatively high canopy percentages within residential parcels, and low values in commercial, industrial and other land use parcels. The figures on the following two pages illustrate tree canopy percent by land use type for parcels with the 75^{th} percentile indicated as a vertical solid line. Census blocks used in the 75^{th} Percentile Rule process are not shown below but are included in other project files.



Histograms of percent canopy cover of parcels and by land use. The gray vertical lines represent existing canopy cover percent (gray, left line) and the canopy cover percent at the 75th percentile (black, right line) for each category identified in the graph title. The count of parcels left of the 75th percentile line are below and count to the right of the line are above the 75th percentile goal.



(continued from previous page). Histograms of percent canopy cover of parcels and by land use. The gray vertical lines represent existing canopy cover percent (gray, left line) and the canopy cover percent at the 75th percentile (black, right line) for each category identified in the graph title. The count of parcels left of the 75th percentile line are below and count to the right of the line are above the 75th percentile goal.

Determination of Tree Species for CommunityViz Tools and Eco Benefits

The Keystone Concept and City of Boise's city forester Brian Jorgenson determined the following list of trees, by genus, to use for current and future tree benefits modeling values as inputs to CommunityViz scenario and GIS design tools. Resources considered when selecting species included i-Tree Species ranking of species for air quality, storm water, and other benefits along with Boise's most recent tree inventory data. The list reflects the most representative current as well as likely future "top 12" tree genera in the landscapes and streets of the Treasure Valley. Additional rationale and caveats involved in this discussion are as follows:

- This list shows diversity in genera while also recognizing that these are the most predominant genera in the TV currently and most likely to be in the future. It was kept to 12 given the amount of time required to generate "lookup table values" using i-Tree software version-5.0.
- This list should not be looked at as a "best local tree palate" for urban forest managers. Rather, is is a "short list" of species specifically for the design of a "what-if" tool used to model canopy benefits. Local managers are encouraged to look at ways to enhance diversity of the urban forest with species and genera outside of this list that are suitable for the local climate and individual site conditions.
- While it is possible to some degree to model current and future benefits based on the "best or worst" trees for air quality, storm water, etc., it was deemed most sensible to model and use the most predominant species based on street tree inventory data and 2011 i-Tree Eco plot data. While at a project specific level it can be valuable to select species that best meet certain benefit types (air quality, energy savings, stormwater, etc.), we should not recommend or implement regional tree planting strategies or policies that aim to, for example, replace all high BVOC emitting species with low BVOC emitting species.
- It should also be understood that there are limitations with current i-Tree benefits modeling. For example, the energy conservation benefits used in i-Eco .v5 only consider conifer vs. deciduous categories, not individual tree species or even genera-level.

In no particular order, Treasure Valley's predominant tree genera for landscape / street trees chosen for the modeling and tools in this project are as follows:

Conifer

Spruce (Picea) and Pine (Pinus).

Deciduous

Ash (Fraxinus), Oak (Quercus), Pear (Pyrus), Maple (Acer), Honeylocust (Gleditsia), Linden (Tilia), Sycamore (Platanus), Sweet Gum (Liquidambar), Birch (Betula), and Elm (Ulmus).

Appendix D: Training Session

TV CORE TEAM TRAINING SESSION – FINAL AGENDA March 18, 2013 9am – 5pm

Agenda Item	Time	Speaker(s)	Description	Format/Files
Introductions & Getting started	9-9:30	DS, LD, IH	Roundtable Introductions & How we got here and where we're headed!	Open discussion
Overview	9:30-10:00	DS, LD, IH	Project results and deliverables	PowerPoint, Files/Folders
GIS Basics	10:00-10:30	IH, DS	Tutorial on GIS background data & how it's used to develop TV Canopy Project tools	ArcMap / ArcCatalog
BREAK	10:30-10:45		Restrooms & Refreshments	
Simple Tools	10:45-11:15	IH	How to use PDF maps & Canopy Calculator tool	PDF / Excel / ArcMap
Tool Time!	11:15-11:45		Play with the GIS data and two tools above, ask questions, etc.	PDF / Excel
Project Integration with i-Tree	11:45-12	IH, DS	How i-Tree Eco was used to support Ecosystem benefit tools. – Background for afternoon session	i-Tree (www), GIS/.xls tables, PowerPoint
BREAK	12:00-1		Lunch on your own (many walkable options)	
CommunityViz (CV) Tools	1-1:30	IH	Basics, CV components, overview of tools/process/functions/uses	ArcMap / CV
CV for Priority Tree Planting	1:30-1:45	IH, DS	Suitability model, factors, weights. – Nampa examples	ArcMap / CV / open forum
Tool Time!	1:45-2		Play with the "suitability model" – use your local tools or AOI	ArcMap / CV
BREAK	2-2:15		Restrooms, Stretch, and Q&A	
Regional Tools	2:15-2:30	IH	Using "Saved Views" for Air Quality	ArcMap / CV
Regional Tools	2:30-2:45	IH	Using "Saved Views" for Energy Conservation	ArcMap / CV
Regional Tools	2:45-3	IH	Using "Saved Views" for Stormwater	ArcMap / CV
Site-Level CV Tools	3-3:15	IH	Add/track trees/costs, create side-by-side comparison scenarios	ArcMap / CV
Tool Time!	3:15-3:30	IH	Play with the tools, ask questions	ArcMap / CV
BREAK	3:30-3:40		Restrooms & Stretch	
DISCUSSION	3:40-4:45	DS, LD	Discuss and Share questions, future uses, ideas. potential demo's directed by questions	All
Closing comments	4:45-5	DS, LD	Recap of ideas, next steps	

* **Speakers:** DS (Dave Stephenson), LD (Lance Davisson), IH (Ian Hanou)
* **Format/Files:** describes the format for that session or files/tools/software used

Treasure Valley Training Attendees:

Name	Agency / Organization
Adam Van Patten	Ada County Highway District
Erica Anderson Maguire	Ada County Highway District
Scott Koberg	Ada County Soil and Water Conservation District
Susan Mason	Boise State University
Michail Fragkias	Boise State University
Scott Lowe	Boise State University
Brian Jorgenson	City of Boise
Debbie Cook	City of Boise
Sam Gould	City of Boise
Angie Hopf	City of Caldwell
Natalie Reeder	City of Kuna
Mike Borzick	City of Kuna
Elroy Huff	City of Meridian
Doug Green	City of Meridian
Kristi Watkins	City of Nampa
Rodney Ashby	City of Nampa
Ian Shives	Community Planning Association of Southwest Idaho (COMPASS)
Tim Maguire	Ecosystem Sciences
Gerry Bates	40 Solutions
David Stephenson	Idaho Department of Lands
Patti Best	Idaho Power
Chris Huck	Idaho Power
Ian Hanou	Plan-It Geo, LLC
Lance Davisson	The Keystone Concept, LLC
Margie Ewing	USDA - Forest Service

Appendix E: i-Eco Version 5 Report

i-Tree

Ecosystem Analysis

Treasure Valley

Urban Forest Effects and Values

May 2013

i-Tree

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Treasure Valley urban forest was conducted during 2011. Data from 250 field plots located throughout Treasure Valley were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

Key findings

- Number of trees: 2,432,000
- Tree cover: 7.3%
- Most common species: Blue spruce, Black locust, Northern white cedar
- Percentage of trees less than 6" (15.2 cm) diameter: 50.9%
- Pollution removal: 581 tons/year ($7.50 million/year)
- Carbon storage: 410,000 tons ($29.2 million)
- Carbon sequestration: 15,500 tons/year ($1.10 million/year)
- Oxygen production: 27,000 tons/year ($0 /year)
- Building energy savings: $-213,000/year
- Avoided carbon emissions: $-102,000/year
- Stormwater runoff mitigation: 125 million gallons/year ($1.12 million/year)
- Structural values: $2.97 billion

Ton: short ton (U.S.) (2,000 lbs)

Carbon storage: the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation Carbon sequestration: the removal of carbon dioxide from the air by plants

Carbon storage and carbon sequestration values are calculated based on $71 per ton

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

Pollution removal value is calculated based on the prices of $1136 per ton (carbon monoxide), $15794 per ton (PM10). Ozone, sulfur dioxide, nitrogen dioxide and particulate matter less than 2.5 microns are calculated based on US EPA BenMAP model.

Energy saving value is calculated based on the prices of $80.4 per MWH and $11.87 per MBTU Monetary values ($) are reported in US Dollars throughout the report except where noted

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control. Additionally, some of the plot and tree information may not have been collected, so not all of the analyses may have been conducted for this report.

Table of Contents

I. Tree Characteristics of the Urban Forest

The urban forest of Treasure Valley has an estimated 2,432,000 trees with a tree cover of 7.30 percent. Trees that have diameters less than 6-inches (15.2 cm) constitute 50.9 percent of the population. The three most common species are Blue spruce (8.5 percent), Black locust (8.2 percent), and Northern white cedar (7.1 percent).

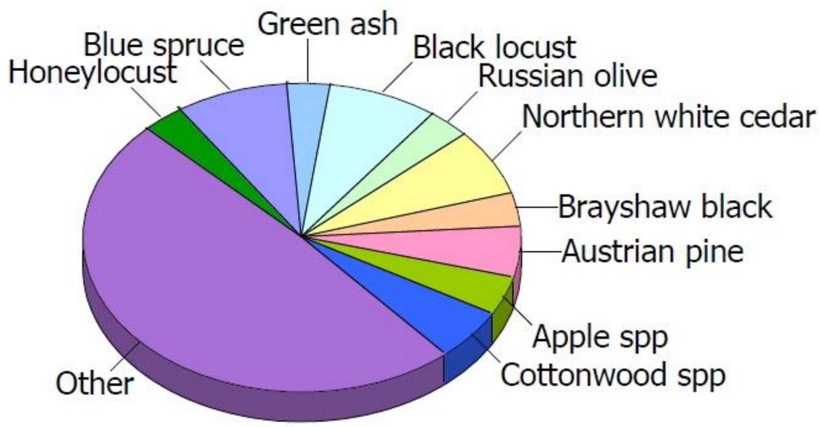


Figure 1. Tree species composition in Treasure Valley

The overall tree density in Treasure Valley is 14.3 trees/acre (see Appendix III for comparable values from other cities).

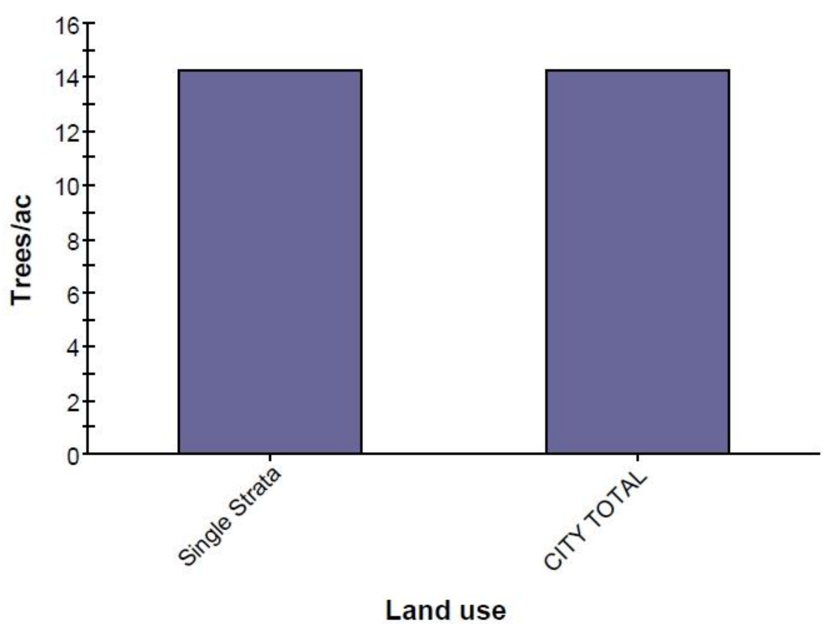


Figure 2. Number of trees/ac in Treasure Valley by land use

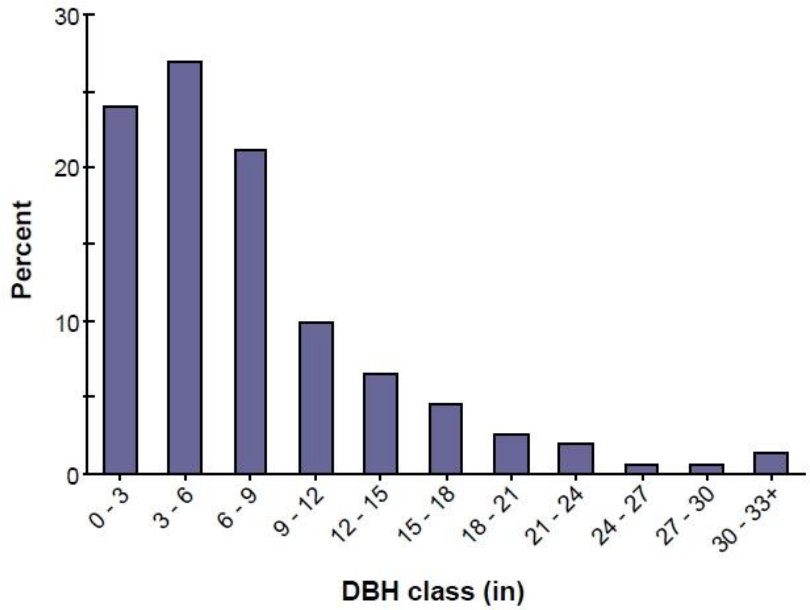


Figure 3. Percent of tree population by diameter class (DBH=stem diameter at 4.5 feet)

Urban forests are composed of a mix 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 by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Treasure Valley, about 52 percent of the trees are species native to North America, while 18 percent are native to the state or district. Species exotic to North America make up 48 percent of the population. Most exotic tree species have an origin from Europe & Asia (18.7 percent of the species).

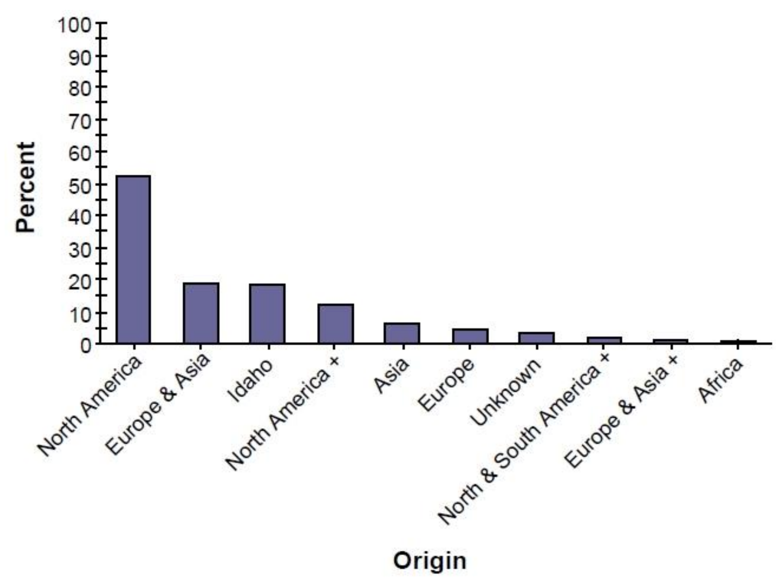


Figure 4. Percent of live trees by species origin

The plus sign (+) indicates the plant is native to another continent other than the ones listed in the grouping.

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 [1]. Zero of the 83 tree species sampled in Treasure Valley is identified as invasive on the state invasive species list [2].

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. In Treasure Valley, the three most dominant species in terms of leaf area are Black locust, Blue spruce, and Austrian pine. Trees cover about 7.3 percent of Treasure Valley, and shrubs cover 3.7 percent.

The 10 most important species are listed in Table 1. Importance values (IV) are calculated as the sum of relative leaf area and relative composition.

Table 1. Most important species in Treasure Valley

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Black locust	8.2	11.2	19.3
Blue spruce	8.5	7.1	15.6
Austrian pine	5.4	4.9	10.2
Cottonwood spp	5.4	3.2	8.5
Northern white cedar	7.1	1.2	8.3
Honeylocust	3.1	4.4	7.5
Apple spp	4.0	3.2	7.2
Brayshaw black	3.4	3.7	7.1
cottonwood Russian olive	3.1	3.7	6.8
Siberian elm	2.5	4.2	6.7

The two most dominant ground cover types are Herbs (31.8 percent) and Grass (15.7 percent).

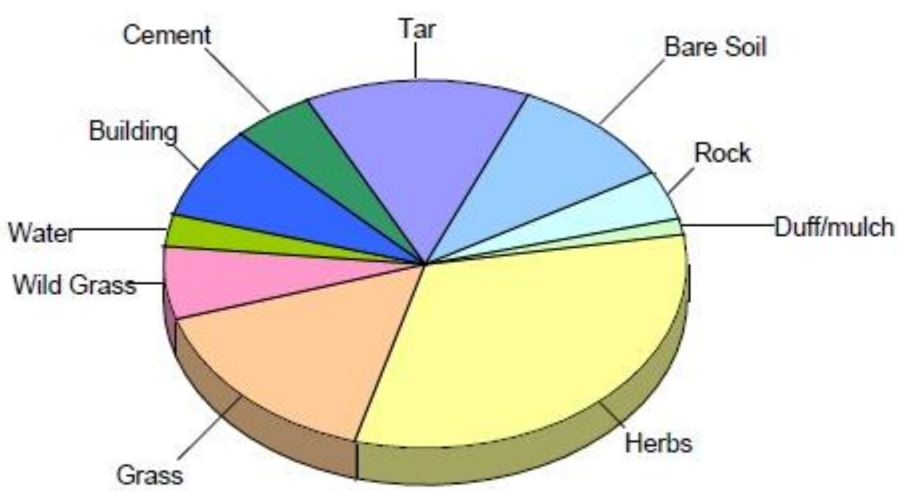


Figure 5. Percent ground cover in Treasure Valley

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. 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 the power plants. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation [3].

Pollution removal by trees and shrubs in Treasure Valley was estimated using field data and recent available pollution and weather data. Pollution removal was greatest for ozone. It is estimated that trees and shrubs remove 581 tons of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 10 microns (PM10), particulate matter less than 2.5 microns (PM2.5), and sulfur dioxide (SO2)) per year with an associated value of $7.50 million based on estimated local incidence of adverse health effects of the BenMAP model and national median externality costs associated with pollutants [5].

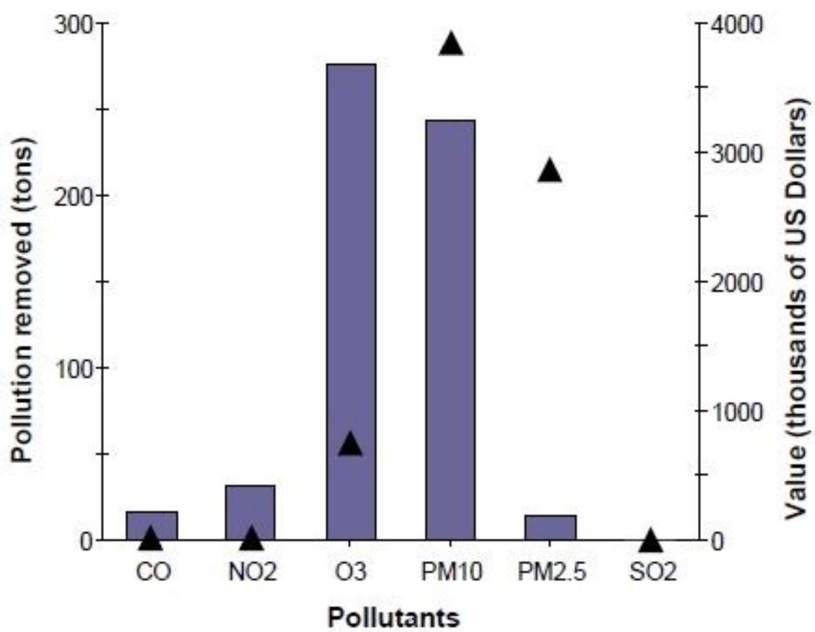


Figure 6. Pollution removal (bars) and associated value (points) for trees in Treasure Valley Pollution removal and value for PM10 excludes PM2.5 removal and value

IV. 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 and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power plants [7].

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 gross sequestration of Treasure Valley trees is about 15,500 tons of carbon per year with an associated value of $1.10 million. Net carbon sequestration in the urban forest is about 10,100 tons. Carbon storage and carbon sequestration values are calculated based on $71 per ton.

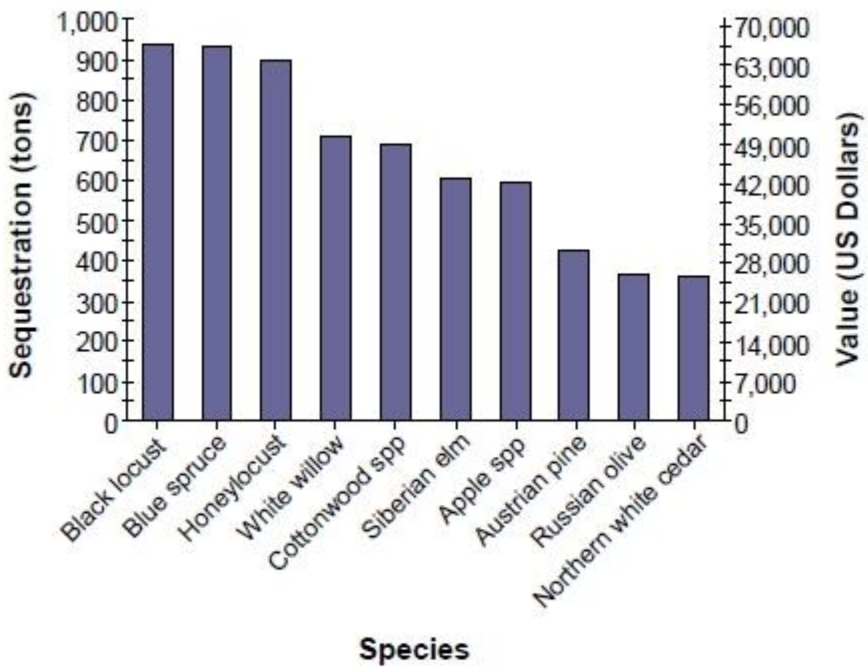


Figure 7. Carbon sequestration and value for species with greatest overall carbon sequestration in Treasure Valley

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 Treasure Valley are estimated to store 410,000 tons of carbon ($29.2 million). Of all the species sampled, Carolina poplar stores the most carbon (approximately 23.6% of the total carbon stored. Black locust sequesters the most carbon (9.3% of all sequestered carbon.)

V. 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 Treasure Valley are estimated to produce 27,000 tons of oxygen per year. However, this tree benefit is relatively 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. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent [8].

Table 2. The top 20 oxygen production species.

	Oxygen (tons)	*Net Carbon Sequestration (tons/yr)*	*Number of trees*	Leaf Area (square miles)
Black locust	2,493.60	935.10	199,200.00	13.25
Blue spruce	2,480.38	930.14	206,069.00	8.48
Honeylocust	2,398.89	899.59	75,559.00	5.25
White willow	1,883.66	706.37	13,738.00	2.47
Cottonwood spp	1,834.30	687.86	130,510.00	3.75
Siberian elm	1,614.49	605.43	61,821.00	4.93
Apple spp	1,589.15	595.93	96,165.00	3.80
Austrian pine	1,122.74	421.03	130,510.00	5.79
Russian olive	971.30	364.24	75,559.00	4.34
Northern white cedar	962.39	360.90	171,724.00	1.47
Paradise apple	961.13	360.42	41,214.00	2.37
River birch	837.70	314.14	27,476.00	1.84
Silver maple	788.99	295.87	34,345.00	3.94
Cherry plum	787.31	295.24	41,214.00	1.02
White ash	701.01	262.88	34,345.00	2.19
Swamp white oak	678.94	254.60	6,869.00	2.04
European hornbeam	638.02	239.26	20,607.00	1.36
Littleleaf linden	598.42	224.41	13,738.00	3.04
Norway maple	562.80	211.05	48,083.00	1.33
Green ash	544.92	204.35	75,559.00	4.10

VI. Trees and 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. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings [9].

Based on 2002 prices, trees in Treasure Valley are estimated to reduce energy-related costs from residential buildings by $-213,000 annually. Trees also provide an additional $-102,129 in value [10] by reducing the amount of carbon released by fossil-fuel based power plants (a reduction of -1,430 tons of carbon emissions). (Note: negative emission values mean that there was not a reduction in carbon emissions, rather carbon emissions and values increased by the amount shown as a negative value.)

Table 3. Annual energy savings due to trees near residential buildings. Note: negative numbers indicate an increased energy use or carbon emission.

	Heating	*Cooling*	*Total*
MBTU[1]	-96,830	n/a	-96,830
MWH[2]	-939	12,580	11,641
Carbon avoided (t[3])	-1,990	556	-1,434

[1]One million British Thermal Units

[2]Megawatt-hour

[3]Short ton

Table 4. Annual savings[1] ($) in residential energy expenditure during heating and cooling seasons. Note: negative numbers indicate a cost due to increased energy use or carbon emission.

	Heating	*Cooling*	*Total*
MBTU[2]	-1,149,356	n/a	-1,149,356
MWH[3]	-75,496	1,011,432	935,936
Carbon avoided	-141,693	39,564	-102,129

[1]Based on the prices of $80.4 per MWH and $11.87 per MBTU

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

VII. Structural and Functional Values

Urban forests have a structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees [11]. 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 also can decrease as the amount of healthy tree cover declines.

Structural values:

- Structural value: $2.97 billion
- Carbon storage: $29.2 million

Annual functional values:

- Carbon sequestration: $1.10 million
- Pollution removal: $7.50 million
- Lower energy costs and carbon emission reductions: $-316,000 (Note: negative value indicates increased energy cost and carbon emission value)

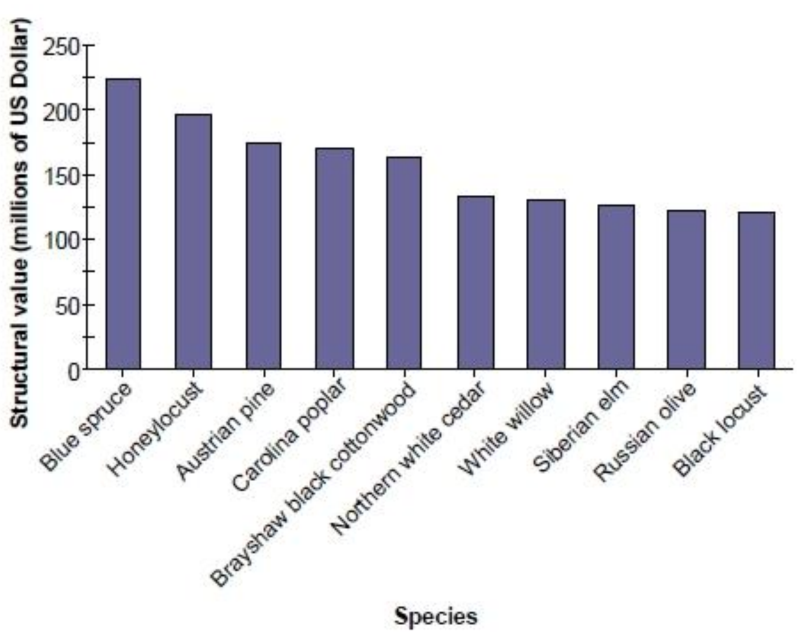


Figure 8. Structural value of the 10 most valuable tree species in Treasure Valley

VIII. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities. Thirty-one pests were analyzed for their potential impact and compared with pest range maps [12]for the conterminous United States. In the following graph, 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; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.

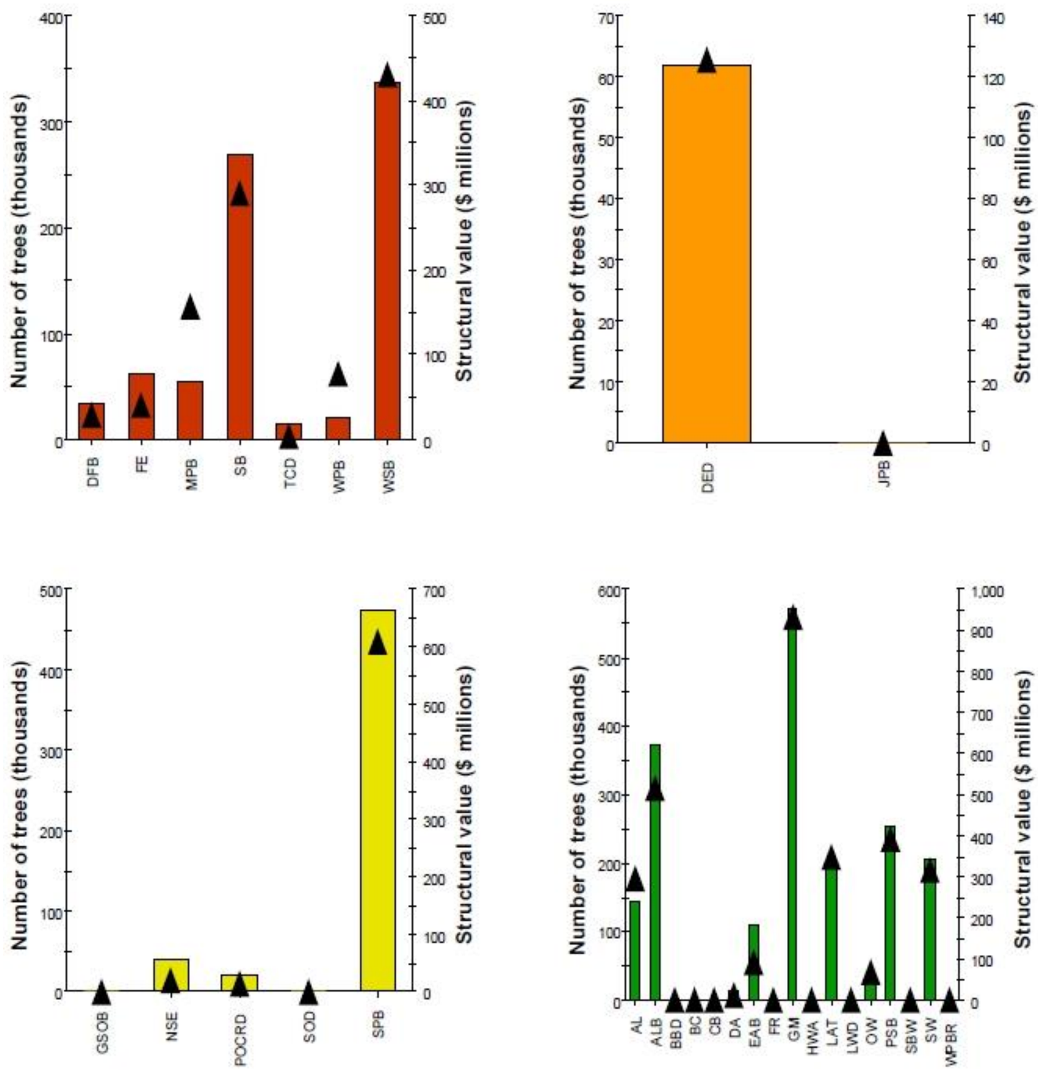


Figure 9. Number of susceptible Treasure Valley trees and structural value by pest (points)

Aspen Leafminer (AL) [13] is an insect that causes damage primarily to trembling or small tooth aspen by larval feeding of leaf tissue. AL has the potential to affect 5.9 percent of the population ($298 million in structural value).

Asian Longhorned Beetle (ALB) [14] is an insect that bores into and kills a wide range of hardwood species. ALB poses a threat to 15.3 percent of the Treasure Valley urban forest, which represents a potential loss of $515 million in structural value.

Beech Bark Disease (BBD) [15] is an insect-disease complex that primarily impacts American beech. This disease threatens 0.0 percent of the population, which represents a potential loss of $0 in structural value.

Butternut Canker (BC) [16] is caused by a fungus that infects butternut trees. The disease has since caused significant declines in butternut populations in the United States. Potential loss of trees from BC is 0.0 percent ($0 in structural value).The most common hosts of the fungus that cause Chestnut Blight (CB) [17] are

American and European chestnut. CB has the potential to affect 0.0 percent of the population($0 in structural value).Dogwood Anthracnose (DA) [18] is a disease that affects dogwood species, specifically flowering and Pacific dogwood. This disease threatens 0.6 percent of the population, which represents a potential loss of $11.0 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) [19]. Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Treasure Valley could possibly lose2.5 percent of its trees to this pest ($126 million in structural value).

Douglas-Fir Beetle (DFB) [20] is a bark beetle that infests Douglas-fir trees throughout the western United States, British Columbia, and Mexico. Potential loss of trees from DFB is 34.3 thousand ($28.5 million in structural value).

Emerald Ash Borer (EAB) [21] has killed thousands of ash trees in parts of the United States. EAB has the potential to affect 4.5 percent of the population ($90.2 million in structural value).

One common pest of white fir, grand fir, and red fir trees is the Fir Engraver (FE)[22]. FE poses a threat to 2.5 percent of the Treasure Valley urban forest, which represents a potential loss of $40.0 million in structural value.

Fusiform Rust (FR) [23] is a fungal disease that is distributed in the southern United States. It is particularly damaging to slash pine and loblolly pine. FR has the potential to affect 0.0 percent of the population ($0 in structural value).

The Gypsy Moth (GM) [25] is a defoliator that feeds on many species causing widespread defoliation and tree death if outbreak conditions last several years. This pest threatens 23.4 percent of the population, which represents a potential loss of $932 million in structural value.

Infestations of the Goldspotted Oak Borer (GSOB) [24] have been a growing problem in southern California. Potential loss of trees from GSOB is $0 ($0 in structural value).

As one of the most damaging pests to eastern hemlock and Carolina hemlock, Hemlock Woolly Adelgid (HWA) [26] has played a large role in hemlock mortality in the United States. HWA has the potential to affect 0.0 percent of the population ($0 in structural value).

The Jeffrey Pine Beetle (JPB) [27] is native to North America and is distributed across California, Nevada, and Oregon where its only host, Jeffrey pine, also occurs. This pest threatens 0.0 percent of the population, which represents a potential loss of $0 in structural value.

Quaking aspen is a principal host for the defoliator, Large Aspen Tortrix (LAT) [28].LAT poses a threat to 192 thousand percent of the Treasure Valley urban forest, which represents a potential loss of $350 million in structural value.

Laurel Wilt (LWD) [29] is a fungal disease that is introduced to host trees by the redbay ambrosia beetle. This pest threatens 0.0 percent of the population, which represents a potential loss of $0 in structural value.

Mountain Pine Beetle (MPB) [30] is a bark beetle that primarily attacks pine species in the western United States. MPB has the potential to affect 2.3 percent of the population($157 million in structural value).

The Northern Spruce Engraver (NSE) [31] has had a significant impact on the boreal and sub-boreal forests of North America where the pest's distribution overlaps with the range of its major hosts. Potential loss of trees from NSE is 41.2 thousand ($20.1 million in structural value).

Oak Wilt (OW) [32], which is caused by a fungus, is a prominent disease among oak trees. OW poses a threat to 0.8 percent of the Treasure Valley urban forest, which represents a potential loss of $66.3 million in structural value.

Port-Orford-Cedar Root Disease (POCRD) [33] is a root disease that is caused by a fungus. POCRD threatens 0.8 percent of the population, which represents a potential loss of$13.6 million in structural value.

The Pine Shoot Beetle (PSB) [34] is a wood borer that attacks various pine species, though Scotch pine is the preferred host in North America. PSB has the potential to affect10.5 percent of the population ($392 million in structural value).

Spruce Beetle (SB) [35] is a bark beetle that causes significant mortality to spruce species within its range. Potential loss of trees from SB is 268 thousand ($292 million in structural value).

Spruce Budworm (SBW) [36] is an insect that causes severe damage to balsam fir.SBW poses a threat to 0.0 percent of the Treasure Valley urban forest, which represents a potential loss of $0 in structural value.

Sudden Oak Death (SOD) [37] is a disease that is caused by a fungus. Potential loss of trees from SOD is $0 ($0 in structural value).

Although the Southern Pine Beetle (SPB) [38] will attack most pine species, its preferred hosts are loblolly, Virginia, pond, spruce, shortleaf, and sand pines. This pest threatens 19.5 percent of the population, which represents a potential loss of $608 million in structural value.

The Sirex Wood Wasp (SW) [39] is a wood borer that primarily attacks pine species. SW poses a threat to 8.5 percent of the Treasure Valley urban forest, which represents a potential loss of $317 million in structural value.

Thousand Canker Disease (TCD) [40] is an insect-disease complex that kills several species of walnuts, including black walnut. Potential loss of trees from TCD is 13.7 thousand($3.91 million in structural value).

The Western Pine Beetle (WPB) [41] is a bark beetle and aggressive attacker of ponderosa and Coulter pines. This pest threatens 0.8 percent of the population, which represents a potential loss of $77.6 million in structural value.

Since its introduction to the United States in 1900, White Pine Blister Rust (Eastern U.S.) (WPBR) [42] has had a detrimental effect on white pines, particularly in the Lake States. WPBR has the potential to affect 0.0 percent of the population ($0 in structural value).

Western spruce budworm (WSB) [43] is an insect that causes defoliation in western conifers. This pest threatens 13.8 percent of the population, which represents a potential loss of $430 million in structural value.

Appendix I. i-Tree Eco Model and Field Measurements

i-Tree Eco 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 [10], 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 (<2.5microns 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 well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

In the field 0.10 acre plots were randomly distributed. Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Within each plot, typical data collection (actual data collection may vary depending upon the user) includes 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[44, 6].

Invasive species were identified using an invasive species list [2] for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. 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.

To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations [45]. To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted 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.

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 [46].

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 [47, 48]. 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 [49, 50] that were adjusted depending on leaf phenology and leaf area. Removal estimates of particulate matter less than 10 microns incorporated a 50 percent resuspension rate of particles back to the atmosphere [51]. 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 [52, 53, and 54].

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 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[5].

National median externality costs were used to calculate the value of carbon monoxide removal. As particulate matter <10 microns is inclusive of particulate matter <2.5microns, the pollution removal value for particulate matter <10 microns utilizes both local incidence values from particulate matter <2.5 microns and national median externality costs from particulate matter <10 microns to estimate the air pollution removal values. Thus the value for particulate matter <10 microns = ((PM10 (mt/yr)-PM2.5 (mt/yr))*median externality)+PM2.5 ($/yr).

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature [9] using distance and direction of trees from residential structures, tree height and tree condition data.

Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information[55].

Potential pest risk was based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps from the Forest Health Technology Enterprise Team (FHTET) [12] were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 250 miles of the county edge, is between250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively [12].

Appendix II. Relative Tree Effects

The urban forest in Treasure Valley 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 [56], average passenger automobile emissions [57], and average household emissions [58].

Carbon storage is equivalent to:

- Amount of carbon emitted in Treasure Valley in 41 days
- Annual carbon (C) emissions from 246,000 automobiles
- Annual C emissions from 124,000 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 64 automobiles
- Annual carbon monoxide emissions from 267 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 1,940 automobiles
- Annual nitrogen dioxide emissions from 1,290 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 803 automobiles
- Annual sulfur dioxide emissions from 14 single-family houses

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

- Annual PM10 emissions from 684,000 automobiles
- Annual PM10 emissions from 66,100 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Treasure Valley in 1.6 days
- Annual C emissions from 9,300 automobiles
- Annual C emissions from 4,700 single-family houses

Note: estimates above are partially based on the user-supplied information on human population total for study area

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" 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.

I. City totals for trees

	% Tree Cover	*Number of trees*	*Carbon storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution removal (tons/yr)*
Calgary, Canada	7.2	11,889,000	445,000	21,422	326
Atlanta, GA	36.8	9,415,000	1,345,000	46,433	1,662
Toronto, Canada	20.5	7,542,000	992,000	40,345	1,212
New York, NY	21.0	5,212,000	1,351,000	42,283	1,677
Baltimore, MD	21.0	2,627,000	596,000	16,127	430
Philadelphia, PA	15.7	2,113,000	530,000	16,115	576
Washington, DC	28.6	1,928,000	523,000	16,148	418
Boston, MA	22.3	1,183,000	319,000	10,509	284
Woodbridge, NJ	29.5	986,000	160,000	5561.00	210
Minneapolis, MN	26.5	979,000	250,000	8,895	305
Syracuse, NY	23.1	876,000	173,000	5,425	109
Morgantown, WV	35.9	661,000	94,000	2,940	66
Moorestown, NJ	28.0	583,000	117,000	3,758	118
Jersey City, NJ	11.5	136,000	21,000	890	41
Freehold, NJ	34.4	48,000	20,000	545	21

II. Per acre values of tree effects

	No. of trees	*Carbon storage (tons)*	*Carbon sequestration (lbs/yr)*	*Pollution removal (lbs/yr)*
Calgary, Canada	66.7	2.5	0.120	3.6
Atlanta, GA	111.6	15.9	0.550	39.4
Toronto, Canada	48.3	6.4	0.258	15.6
New York, NY	26.4	6.8	0.214	17.0
Baltimore, MD	50.8	11.5	0.312	16.6
Philadelphia, PA	25.0	6.3	0.190	13.6
Washington, DC	49.0	13.3	0.410	21.2
Boston, MA	33.5	9.0	0.297	16.0
Woodbridge, NJ	66.5	10.8	0.375	28.4
Minneapolis, MN	26.2	6.7	0.238	16.4
Syracuse, NY	54.5	10.8	0.338	13.6
Morgantown, WV	119.7	17.0	0.532	23.8
Moorestown, NJ	62.0	12.5	0.400	25.2
Jersey City, NJ	14.3	2.2	0.094	8.6
Freehold, NJ	38.5	16.0	0.437	33.6

Appendix IV. 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 [59]:

- 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[60]. Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include [61]:

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 V. Invasive Species of the Urban Forest

The following inventoried species were listed as invasive on the Idaho invasive species list [2]:

	Number of trees	*% Tree Number*	*Leaf Area (mi2)*	*% Leaf Area*
TOTAL	**0**	**<0.01**	**0.00**	**<0.01**

[1]Species are determined to be invasive if they are listed on the state's invasive species list.

Appendix VI. Potential risk of pests

Based on the host tree species for each pest and the current range of the pest [12], it is possible to determine what the risk is that each tree species sampled in the urban forest could be attacked by an insect or disease.

			Pest																														
Spp Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	CB	DA	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	POCRD	PSB	SB	SBW	SOD	SPB	SW	TCD	WPB	WPBR	WSB
red	16	Engelmann spruce										red									yellow				red			yellow					red
red	16	Ponderosa pine																		red				green				yellow	green		red		red
red	15	Norway spruce																		red				green	red			yellow					red
red	13	Douglas fir								red		red												green									red
red	12	White spruce																			yellow				red			yellow					red
red	12	Scotch pine																		red				green				yellow	green				red
red	10	Blue spruce																							red			yellow					red
red	6	Serbian spruce																							red			yellow					
red	4	Black walnut																												red			
orange	4	Siberian elm		green					orange																								
yellow	4	Austrian pine																						green				yellow	green				
yellow	4	Pine spp																						green				yellow	green				
yellow	4	Sweet mountain pine																						green				yellow	green				
green	4	Quaking aspen	green	green										green				green															
green	4	White willow	green	green										green				green															
green	4	Willow spp	green	green										green				green															
green	3	Brayshaw black cottonwood	green											green				green															
green	3	Paper birch		green										green				green															
green	3	River birch		green										green				green															
yellow	2	Port orford cedar																					yellow										
green	2	Bur oak												green								green											
green	2	English oak												green								green											
green	2	Green ash		green							green																						
green	2	Swamp white oak												green								green											
green	1	Alder spp																green															
green	1	American basswood												green																			
green	1	Amur maple		green																													
green	1	Apple spp												green																			
green	1	Boxelder		green																													
green	1	Callery pear												green																			
green	1	Carolina poplar												green																			
green	1	Cottonwood spp												green																			
green	1	Dogwood spp						green																									
green	1	Flowering dogwood						green																									
green	1	Hawthorn spp												green																			
green	1	Hedge maple		green																													
green	1	Horsechestnut		green																													
green	1	Littleleaf linden												green																			
green	1	London planetree		green																													
green	1	Maple spp		green																													
green	1	Norway maple		green																													
green	1	Paradise apple												green																			
green	1	Pear spp												green																			
green	1	Red maple		green																													
green	1	Silver maple		green																													
green	1	Vine maple		green																													
green	1	Washington hawthorn												green																			
green	1	White ash									green																						

<u>**Note:**</u>

Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 to 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:

Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Ada county
- Orange indicates pest is within 250 miles of Ada county
- Yellow indicates pest is within 750 miles of Ada county
- Green indicates pest is outside of these ranges

References

1. U.S. Department of Agriculture. National Invasive Species Information Center. 2011. http://www.invasivespeciesinfo.gov/plants/main.shtml

2. State invasive species lists were compiled for the following:
AL: Alabama Invasive Plant Council. 2007. Center for Invasive Species and Ecosystem Health at the University of Georgia. http://www.se-eppc.org/alabama/2007plantlist.pdf
AK: Alaska National Heritage Program. University of Alaska Anchorage. http://aknhp.uaa.alaska.edu/botany/akepic/non-native-plant-species-biographies/
AZ: Arizona Wildlands Invasive Plant Working Group. 2005. Invasive Non-Native Plants That Threaten Wildlands in Arizona. http://sbsc.wr.usgs.gov/research/projects/swepic/SWVMA/InvasiveNon-NativePlantsThatThreatenWildlandsInArizona.pdf
AR: Jardine, Jude; Witsell, Theo. Arkansas Native Plant Society. Working List of Non-native Invasive Plant Species of Concern to Natural Areas in Arkansas. http://www.deltic.com/hunting/ANPS%20INVASIVES%20LIST.pdf
CA: California Invasive Species Advisory Committee. 2010. The California Invasive Species List. http://www.iscc.ca.gov/docs/CaliforniaInvasiveSpeciesList.pdf
CO: Colorado Weed Management Association. Colorado Noxious Weed List. http://www.cwma.org/noxweeds.html#list
CT: Connecticut Invasive Plants Council. 2009. Connecticut Invasive Plant List. ftp://ftp-fc.sc.egov.usda.gov/CT/invasives/WordInvasivesListCommonNameW-Authors4PDF.pdf
DF.pdf>DE: McAvoy, William A. 2001. Invasive Plant Species in Delaware. http://www.dnrec.state.de.us/fw/invasive.htm
FL: Florida Exotic Pest Plant Council Plant List Committee. 2007. FLEPPC 2007 List of Invasive Plant Species. http://www.fleppc.org/list/07list_ctrfld.pdf
GA: Georgia Exotic Pest Plant Council. List of Non-native Invasive Plants in Georgia. http://www.gaeppc.org/list.cfm
HI: Hawaii State Alien Species Coordinator. Hawaii's Most Invasive Horticultural Plants. http://www.state.hi.us/dlnr/dofaw/hortweeds/specieslist.htm Hawaii Invasive Species Partnership. Hawaii's High-Profile Invasive Species. http://www.hawaiiinvasivespecies.org/pests/
IL: Invasive.org: Center for Invasive Species and Ecosystem Health. Illinois Invasive Plant List. http://www.invasive.org/species/list.cfm?id=152
IN: Indiana Cooperative Agricultural Pest Survey. 2007. Indiana's "Most Unwanted" Invasive Plant Pest List - FY 2007. http://www.extension.entm.purdue.edu/CAPS/downloads/IndianaInvasivePlantPestList.pdf
Iowa. Forest Invasive Plants Resource Center. Current and Future Invasive Plants. http://na.fs.fed.us/spfo/invasiveplants/states/ia.asp Iowa Department of Natural Resources. Invasive Plant Species. http://www.iowadnr.gov/forestry/invasive.html
KS: Kansas Native Plant Society. 2006. Invasive Plant Fact Sheet. R.L. McGregor Herbarium. University of Kansas. http://www.kansasnativeplantsociety.org/invasive_plants.htm

KY: Kentucky Exotic Pest Plant Council. Center for Invasive Species and Ecosystem Health at the University of Georgia. http://www.se-eppc.org/ky/list.htm

ME: Public Laws of Maine. An Act to Prevent the Spread of Invasive Aquatic Plants. http://www.mainelegislature.org/ros/LOM/LOM119th/5Pub701-750/5Pub701-750-21.htm Department of Conservation. Maine Natural Areas Program. Invasive Plant Fact Sheets. http://www.maine.gov/doc/nrimc/mnap/features/invsheets.htm

MD: Maryland Invasive Species Council. Invasive Species of Concern in Maryland: Terrestrial Plants. http://www.mdinvasivesp.org/list_terrestrial_plants.html Maryland Invasive Species Council. Invasive Species of Concern in Maryland: Aquatic Plants. http://www.mdinvasivesp.org/list_aquatic_plants.html

MA: Massachusetts Invasive Plant Advisory Group. 2005. The Evaluation of Non-native Plant Species for Invasiveness in Massachusetts. http://www.newfs.org/docs/docs/MIPAG040105.pdf

MI: Michigan Natural Features Inventory. Michigan State University Extension. Michigan Invasive Plant Species Account. http://web4.msue.msu.edu/mnfi/education/factsheets.cfm

MN: Minnesota Department of Natural Resources. Invasive Terrestrial Plants. http://www.dnr.state.mn.us/invasives/terrestrialplants/index.html Minnesota Department of Natural Resources. Invasive Aquatic Plants. http://www.dnr.state.mn.us/invasives/aquaticplants/index.html

MS: Winters, Faye; Byrd, John D.; Bryson, Charles T. Mississippi's Ten Worst Invasive Weeds: Threatening Fish and Wildlife Habitat. http://www.wildlifemiss.org/news/news/2004/mississippi_weeds.htm Mississippi Exotic Pest Plant Council. Noteworthy Exotic Plant Species of Mississippi. http://www.se-eppc.org/mississippi/

MO: Missouri Botanical Gardens. Missouri Exotic Pest Plants. http://www.mobot.org/mobot/research/mepp/alphalist.shtml

NE: Nebraska Invasive Species Advisory Council. Invasive Plants of Nebraska. http://snr.unl.edu/invasives/pdfs/Invasive%20Plant%20Lists/NE%20Invasive%20Plants%20List%20Full%20Document%204-14-11.pdf

NV: University of Nevada Cooperative Extension. Invasive Plants in Nevada: An Identification Handbook. http://www.unce.unr.edu/publications/files/ag/other/sp9603.pdf

NH: New Hampshire Department of Agriculture, Markets, and Food. NH Prohibited Invasive Species List. http://www.nh.gov/agric/divisions/plant_industry/documents/list.pdf New Hampshire Department of Agriculture, Markets, and Food. NH Restricted Invasive Species List. http://www.nh.gov/agric/divisions/plant_industry/documents/watch.pdf Cygan, Douglas. New Hampshire Department of Agriculture, Markets, and Food. New Hampshire Invasive Species Committee. 2011. Guide to Invasive Upland Plant Species in New Hampshire. http://extension.unh.edu/Forestry/Docs/invasive.pdf

NJ: The Native Plant Society of New Jersey. 2004. Appendix to Policy Directive 2004-02 Invasive Nonindigenous Plant Species. http://www.npsnj.org/references/invasive_plant_list.pdf Ling, Hubert. 2003. Invasive Plant Species. The Native Plant Society of New Jersey. http://www.npsnj.org/invasive_species_0103.htm

NY: New York State Department of Environmental Conservation. Interim Invasive Species Plant List. http://www.dec.ny.gov/animals/65408.html

NC: Smith, Cherri. 2008. Invasive Exotic Plants of North Carolina. North Carolina Department of Transportation. http://www.se-eppc.org/northcarolina/NCDOT_Invasive_Exotic_Plants.pdf North Carolina Native Plant Society. 2010. Invasive Exotic Species List. http://www.ncwildflower.org/invasives/list.htm

ND: North Dakota Department of Agriculture. Catalogue of Species. http://www.agdepartment.com/noxiousweeds/searchweeds.asp

OH: Ohio Department of Natural Resources. The Nature Conservancy. 2000. Ohio's Invasive Plant Species. http://www.ohiodnr.com/Portals/3/invasive/pdf/OHIO%20INVASIVE%20PLANTS.pdf

OK: Oklahoma Native Plant Society. Oklahoma Biological Survey. OSU Natural Resource Ecology and Management. Oklahoma Non-native Invasive Plant Species. http://www.ok-invasive-plant-council.org/images/OKinvasivespp.pdf

OR: Oregon Invasive Species Council. 100 Most Dangerous Invaders to Keep Out. http://oregon.gov/OISC/most_dangerous.shtml

PA: Pennsylvania Department of Conservation and Natural Resources. Invasive Exotic Plants in Pennsylvania List. http://www.dcnr.state.pa.us/forestry/invasivetutorial/List.htm

RI: Rhode Island Invasive Species Council. Rhode Island Natural History Survey. 2001. Invasives: List. http://www.rinhs.org/resources/ri-invasive-species-resources/invasive-list/

SC: South Carolina Exotic Pest Plant Council. Center for Invasive Species and Ecosystem Health at the University of Georgia. http://www.invasive.org/species/list.cfm?id=27 South Carolina Exotic Pest Plant Council Invasive Species List 2008. http://www.se-eppc.org/southcarolina/invasivePlants.cfm

TN: Tennessee Exotic Pest Plant Council. 2009. Invasive Plants of Tennessee. http://www.tneppc.org/invasive_plants

TX: Watershed Protection Development Review. City of Austin. Central Texas Invasive Plants. Volunteer Field Guide. http://www.ci.austin.tx.us/growgreen/downloads/invasiveplants.pdf

VT: Vermont Invasive Exotic Plant Committee. 2005. Invasive Species Watch List for Vermont. http://www.vtinvasiveplants.org/pdfs/VIEPC%20Invasive%20Watch%20List.pdf List of invasive terrestrial plants known to be in Vermont or on our borders. Developed by Vermont Invasive Exotic Plant Committee. In: Developing Invasive Plant Outreach and Management Projects. The Nature Conservancy http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/vermont/chapter-1-23-for-web.pdf VA: Virginia Native Plant Society. Department of Conservation and Recreation. 2009. Invasive Alien Plant Species of Virginia. http://www.dcr.virginia.gov/natural_heritage/documents/invlist.pdf

WV: West Virginia Division of Natural Resources. Dirty Dozen. http://www.wvdnr.gov/Wildlife/DirtyDozen.shtm

WI: Wisconsin Department of Natural Resources. Invasive Species. Terrestrial Invasives - Plants. http://dnr.wi.gov/invasives/species.asp?filterBy=Terrestrial&filterVal=Y&catVal=Plants Wisconsin Department of Natural Resources. Invasive Species. Aquatic Invasives - Plants. http://dnr.wi.gov/invasives/species.asp?filterBy=Aquatic&filterVal=Y&catVal=Plants

3. Nowak D.J. and Dwyer J.F. "Understanding the Benefits and Costs of Urban Forest Ecosystems." Handbook of Urban and Community Forestry in the Northeast. Ed. John E. Kuser. Kluwer Academics/Plenum Pub., New York. 2000. 11-22.
4. Murray, F.J.; Marsh L.; Bradford, P.A. 1994. New York State Energy Plan, vol. II: issue reports. Albany, NY: New York State Energy Office.
5. Davidson, K., A. Hallberg, D. McCubbin, and B. Hubbell. (2007). Analysis of PM2.5 Using the Environmental Benefits Mapping and Analysis Program (BenMAP). Journal of Toxicology and Environmental Health, Part A 70(3): 332-346.
6. Nowak, D.J., R.E. Hoehn, D.E. Crane, J.C. Stevens, J.T. Walton, and J. Bond. 2008. A ground-based method of assessing urban forest structure and ecosystem services. Arboric. Urb. For. 34(6): 347-358.
7. Abdollahi, K.K.; Z.H. Ning; and A. Appeaning (eds). 2000. Global climate change and the urban forest. Baton Rouge, LA: GCRCC and Franklin Press. 77p.
8. Broecker, W.S. 1970. Man's oxygen reserve. Science 168: 1537-1538.
9. McPherson, E.G. and J. R. Simpson 1999. Carbon dioxide reduction through urban forestry: guidelines for professional and volunteer tree planters. Gen. Tech. Rep. PSW-171. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research station 237 p. http://wcufre.ucdavis.edu/products/cufr_43.pdf
10. Nowak, D.J., and D.E. Crane. 2000. The Urban Forest Effects (UFORE) Model: quantifying urban forest structure and functions. In: Hansen, M. and T. Burk (Eds.) Integrated Tools for Natural Resources Inventories in the 21st Century. Proc. Of the IUFRO Conference. USDA Forest Service General Technical Report NC-212. North Central Research Station, St. Paul, MN. pp. 714-720. See also http://www.ufore.org.
11. Nowak, D.J.; Crane, D.E.; Dwyer, J.F. 2002. Compensatory value of urban trees in the United States. Journal of Arboriculture. 28(4): 194 - 199.
12. Insect/disease proximity to study area was completed using the U.S. Forest Service's Forest Health Technology Enterprise Team (FHTET) database. Data includes distribution of pest by county FIPs code for 2004-2009. FHTET range maps are available at www.foresthealth.info for 2006-2010.
13. Kruse, James; Ambourn, Angie; Zogas, Ken 2007. Aspen Leaf Miner. Forest Health Protection leaflet. R10-PR-14. United States Department of Agriculture, Forest Service, Alaska Region. Can be accessed through: http://www.fs.fed.us/r10/spf/fhp/leaflets/aspen_leaf_miner.pdf
14. Northeastern Area State and Private Forestry. 2005. Asian Longhorned Beetle. Newtown Square, PA: U.S. Department of Agriculture, Northeastern Area State and Private Forestry. http://www.na.fs.fed.us/spfo/alb/
15. Houston, David R.; O'Brien, James T. 1983. Beech Bark Disease. Forest Insect & Disease Leaflet 75. United States Department of Agriculture, Forest Service. 8 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-75.pdf

16. Ostry, M.E.; Mielke, M.E.; Anderson, R.L. 1996. How to Identify Butternut Canker and Manage Butternut Trees. United States Department of Agriculture, Forest Service, North Central Forest Experiment Station. Can be accessed through: http://www.na.fs.fed.us/spfo/pubs/howtos/ht_but/ht_but.htm

17. Diller, Jesse D. 1965. Chestnut Blight. Forest Pest Leaflet 94. United States Department of Agriculture, Forest Service. 7 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-94.pdf

18. Mielke, Manfred E.; Daughtrey, Margery L. How to Identify and Control Dogwood Anthracnose. NA-GR-18. United States Department of Agriculture, Forest Service, Northeastern Area. Can be accessed through: http://na.fs.fed.us/spfo/pubs/howtos/ht_dogwd/ht_dog.htm

19. Northeastern Area State and Private Forestry. 1998. HOW to identify and manage Dutch Elm Disease. NA-PR-07-98. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. http://www.na.fs.fed.us/spfo/pubs/howtos/ht_ded/ht_ded.htm

20. Schmitz, Richard F.; Gibson, Kenneth E. 1996. Douglas-fir Beetle. Forest Insect & Disease Leaflet 5. R1-96-87. United States Department of Agriculture, Forest Service. 8 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-5.pdf

21. Northeastern Area State and Private Forestry. 2005. Forest health protection emerald ash borer home. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. http://www.na.fs.fed.us/spfo/eab/index.html

22. Ferrell, George T. 1986. Fir Engraver. Forest Insect & Disease Leaflet 13. United States Department of Agriculture, Forest Service. 8 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-13.pdf

23. Phelps, W.R.; Czabator, F.L. 1978. Fusiform Rust of Southern Pines. Forest Insect & Disease Leaflet 26. United States Department of Agriculture, Forest Service. 7 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-26.pdf

24. Society of American Foresters. Gold Spotted Oak Borer Hitches Ride in Firewood, Kills California Oaks. Forestry Source. October 2011 Vol. 16, No.10.

25. Northeastern Area State and Private Forestry. 2005. Gypsy moth digest. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. http://na.fs.fed.us/fhp/gm

26. USDA Forest Service. 2005. Hemlock Woolly Adelgid. Pest Alert. NA-PR-09-05. United States Department of Agriculture, Forest Service, Northern Area State and Private Forestry. Can be accessed through: http://na.fs.fed.us/spfo/pubs/pest_al/hemlock/hwa05.htm

27. Smith, Sheri L.; Borys, Robert R.; Shea, Patrick J. 2009. Jeffrey Pine Beetle. Forest Insect & Disease Leaflet 11. United States Department of Agriculture, Forest Service. 8 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-11.pdf

28. Ciesla, William M.; Kruse, James J. 2009. Large Aspen Tortrix. Forest Insect & Disease Leaflet 139. United States Department of Agriculture, Forest Service. 8 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-139.pdf

29. Laurel Wilt. United States Department of Agriculture, Forest Service, Forest Health Protection, Southern Region. Can be accessed through: http://www.fs.fed.us/r8/foresthealth/laurelwilt/

30. Gibson, Ken; Kegley, Sandy; Bentz, Barbara. 2009. Mountain Pine Beetle. Forest Insect & Disease Leaflet 2. United States Department of Agriculture, Forest Service. 12 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-2.pdf

31. Burnside, R.E. et al. 2011. Northern Spruce Engraver. Forest Insect & Disease Leaflet 180. United States Department of Agriculture, Forest Service. 12 p.

32. Rexrode, Charles O.; Brown, H. Daniel 1983. Oak Wilt. Forest Insect & Disease Leaflet 29. United States Department of Agriculture, Forest Service. 6 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-29.pdf

33. Liebhold, A. 2010 draft. Geographical Distribution of Forest Pest Species in US. In: Frontiers in Ecology and the Environment.

34. Ciesla, William M. 2001. Tomicus piniperda. North American Forest Commission. Exotic Forest Pest Information System for North America (EXFOR). Can be accessed through: http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=86&langdisplay=english

35. Holsten, E.H.; Thier, R.W.; Munson, A.S.; Gibson, K.E. 1999. The Spruce Beetle. Forest Insect & Disease Leaflet 127. United States Department of Agriculture, Forest Service. 12 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-127.pdf

36. Kucera, Daniel R.; Orr, Peter W. 1981. Spruce Budworm in the Eastern United States. Forest Pest Leaflet 160. United States Department of Agriculture, Forest Service. 8 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-160.pdf

37. Kliejunas, John. 2005. Phytophthora ramorum. North American Forest Commission. Exotic Forest Pest Information System for North America (EXFOR). Can be accessed through: http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=62&langdisplay=english

38. Clarke, Stephen R.; Nowak, J.T. 2009. Southern Pine Beetle. Forest Insect & Disease Leaflet 49. United States Department of Agriculture, Forest Service. 8 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-49.pdf

39. Haugen, Dennis A.; Hoebeke, Richard E. 2005. Sirex woodwasp - Sirex noctilio F. (Hymenoptera: Siricidae). Pest Alert. NA-PR-07-05. United States Department of Agriculture, Forest Service, Northern Area State and Private Forestry. Can be accessed through: http://na.fs.fed.us/spfo/pubs/pest_al/sirex_woodwasp/sirex_woodwasp.htm

40. Seybold, Steven ; Haugen, Dennis; Graves, Andrew. 2010. Thousand Cankers Disease-Pest Alert. NA-PR-02-10. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. Cranshaw, W. and N. Tisserat. c. 2009. Walnut twig beetle and the thousand cankers disease of black walnut. Pest Alert. Colorado State University. http://www.ext.colostate.edu/pubs/insect/0812_alert.pdf

41. DeMars Jr., Clarence J.; Roettgering, Bruce H. 1982. Western Pine Beetle. Forest Insect & Disease Leaflet 1. United States Department of Agriculture, Forest Service. 8 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-1.pdf

42. Nicholls, Thomas H.; Anderson, Robert L. 1977. How to Identify White Pine Blister Rust and Remove Cankers. United States Department of Agriculture, Forest Service, North Central Research Station. Can be accessed through: http://na.fs.fed.us/spfo/pubs/howtos/ht_wpblister/toc.htm

43. Fellin, David G.; Dewey, Jerald E. 1986. Western Spruce Budworm. Forest Insect & Disease Leaflet 53. United States Department of Agriculture, Forest Service. 10 p. Can be accessed through: http://www.fs.fed.us/r6/nr/fid/fidls/fidl-53.pdf

44. Nowak, D.J.; Crane, D.E.; Stevens, J.C.; Hoehn, R.E. 2005. The urban forest effects (UFORE) model: field data collection manual. V1b. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station, 34 p. http://www.fs.fed.us/ne/syracuse/Tools/downloads/UFORE_Manual.pdf

45. Nowak, D.J. 1994. Atmospheric carbon dioxide reduction by Chicago's urban forest. In: McPherson, E.G.; Nowak, D.J.; Rowntree, R.A., eds. Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project. Gen. Tech. Rep. NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 83-94.

46. Nowak, David J., Hoehn, R., and Crane, D. 2007. Oxygen production by urban trees in the United States. Arboriculture & Urban Forestry 33(3):220-226.

47. Baldocchi, D. 1988. A multi-layer model for estimating sulfur dioxide deposition to a deciduous oak forest canopy. Atmospheric Environment. 22: 869-884.

48. Baldocchi, D.D.; Hicks, B.B.; Camara, P. 1987. A canopy stomatal resistance model for gaseous deposition to vegetated surfaces. Atmospheric Environment. 21: 91-101.

49. Bidwell, R.G.S.; Fraser, D.E. 1972. Carbon monoxide uptake and metabolism by leaves. Canadian Journal of Botany. 50: 1435-1439.

50. Lovett, G.M. 1994. Atmospheric deposition of nutrients and pollutants in North America: an ecological perspective. Ecological Applications. 4: 629-650.

51. Zinke, P.J. 1967. Forest interception studies in the United States. In: Sopper, W.E.; Lull, H.W., eds. Forest Hydrology. Oxford, UK: Pergamon Press: 137-161.

52. Hirabayashi, S., C. Kroll, and D. Nowak. (2011). Component-based development and sensitivity analyses of an air pollutant dry deposition model. Environmental Modeling and Software 26(6): 804-816.

53. Hirabayashi, S., C. Kroll, and D. Nowak. (2011). Urban Forest Effects-Dry Deposition (UFORE-D) Model Descriptions, http://www.itreetools.org/eco/resources/UFORE-D%20Model%20Descriptions V11.pdf

54. Hirabayashi, S. (2011). Urban Forest Effects-Dry Deposition (UFORE-D) Model Enhancements, http://www.itreetools.org/eco/resources/UFORE-D enhancements.pdf

55. Nowak, D.J.; Crane, D.E.; Stevens, J.C.; Ibarra, M. 2002. Brooklyn's Urban Forest. Gen. Tech. Rep. NE-290. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 107 p. Council of Tree and Landscape Appraisers guidelines. For more information, see Nowak, D.J., D.E. Crane, and J.F. Dwyer. 2002. Compensatory value of urban trees in the United States. J. Arboric. 28(4): 194-199.

56. Total city carbon emissions were based on 2003 U.S. per capita carbon emissions - calculated as total U.S. carbon emissions (Energy Information Administration, 2003, Emissions of Greenhouse Gases in the United States 2003. http://www.eia.doe.gov/oiaf/1605/ggrpt/) divided by 2003 U.S. total population (www.census.gov). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

57. Average passenger automobile emissions per mile were based on dividing total 2002 pollutant emissions from light-duty gas vehicles (National Emission Trends http://www.epa.gov/ttn/chief/trends/index.html) divided by total miles driven in 2002 by passenger cars (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/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 http://www.bts.gov/publications/national_transportation_statistics/2004/).

Carbon dioxide emissions from automobile assumed six pounds of carbon per gallon of gasoline if energy costs of refinement and transportation are included (Graham, R.L., Wright, L.L., and Turhollow, A.F. 1992. The potential for short-rotation woody crops to reduce U.S. CO2 Emissions. Climatic Change 22:223-238.

58. Average household emissions 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 from: Energy Information Administration. Total Energy Consumption in U.S. Households by Type of Housing Unit, 2001 http://www.eia.doe.gov/emeu/recs/contents.html.

CO2, SO2, and NOx power plant emission per KWh from: U.S. Environmental Protection Agency. U.S. Power Plant Emissions Total by Year www.epa.gov/cleanenergy/egrid/samples.htm.

CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on: Energy Information Administration. 1994 Energy Use and Carbon Emissions: Non-OECD Countries DOE/EIA-0579.

PM10 emission per kWh from: Layton, M. 2004. 2005 Electricity Environmental Performance Report: Electricity Generation and Air Emissions. California Energy Commission. http://www.energy.ca.gov/2005_energypolicy/documents/2004-11-15_workshop/2004-11-15_03-A_LAYTON.PDF

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) from: Abraxas energy consulting, http://www.abraxasenergy.com/emissions/

CO2 and fine particle emissions per Btu of wood from: Houck, J.E. Tiegs, P.E, McCrillis, R.C. Keithley, C. and Crouch, J. 1998. Air emissions from residential heating: the wood heating option put into environmental perspective. In: Proceedings of U.S. EPA and Air Waste Management Association Conference: Living in a Global Environment, V.1: 373-384.

CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from: Residential Wood Burning Emissions in British Columbia, 2005. http://www.env.bc.ca/air/airquality/pdfs/wood_emissions.pdf.

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 from: Heating with Wood I. Species characteristics and volumes. http://ianrpubs.unl.edu/forestry/g881.htm

59. Nowak, D.J. 1995. Trees pollute? A "TREE" explains it all. In: Proceedings of the 7th National Urban Forestry Conference. Washington, DC: American Forests. Pp. 28-30

60. Nowak, D.J. and J.F. Dwyer. 2007. Understanding the benefits and costs of urban forest ecosystems. In: Kuser, J. (ed.) Urban and Community Forestry in the Northeast. New York: Springer. Pp. 25-46.

61. Nowak, D.J. 2000. The interactions between urban forests and global climate change. In: Abdollahi, K.K., Z.H. Ning, and A. Appeaning (Eds). Global Climate Change and the Urban Forest. Baton Rouge: GCRCC and Franklin Press. Pp. 31-44.

Pollutant Removal in Treasure Valley

Series: Regional, Time Period: 2011

		Removal (Short Ton)			Value ($)[1]		
Pollutant	Month	Mean	Max	Min	Mean	Max	Min
CO	1	0.263	0.263	0.263	298.83	298.83	298.83
	2	0.290	0.290	0.290	329.33	329.33	329.33
	3	0.174	0.174	0.174	197.61	197.61	197.61
	4	0.150	0.150	0.150	170.29	170.29	170.29
	5	2.643	2.643	2.643	3,003.16	3,003.16	3,003.16
	6	2.247	2.247	2.247	2,553.60	2,553.60	2,553.60
	7	2.230	2.230	2.230	2,533.96	2,533.96	2,533.96
	8	3.596	3.596	3.596	4,085.96	4,085.96	4,085.96
	9	3.347	3.347	3.347	3,803.34	3,803.34	3,803.34
	10	0.847	0.847	0.847	962.75	962.75	962.75
	11	0.205	0.205	0.205	232.89	232.89	232.89
	12	0.229	0.229	0.229	259.97	259.97	259.97
	Annual	**16.219**	**16.219**	**16.219**	**18,431.70**	**18,431.70**	**18,431.70**
NO2	1	2.061	2.061	2.061	1,094.16	1,094.16	1,094.16
	2	1.767	1.767	1.767	937.91	937.91	937.91
	3	1.230	1.230	1.230	653.08	653.08	653.08
	4	0.913	0.913	0.913	484.39	484.39	484.39
	5	3.016	3.959	1.321	1,600.84	2,101.43	701.33
	6	4.341	5.648	1.573	2,304.11	2,997.90	835.01
	7	3.926	5.877	1.740	2,083.76	3,119.75	923.68
	8	4.558	6.942	2.239	2,419.30	3,684.85	1,188.47
	9	4.540	6.532	2.226	2,409.86	3,467.24	1,181.59
	10	1.659	2.005	1.211	880.36	1,064.33	642.96
	11	1.049	1.049	1.049	556.93	556.93	556.93
	12	1.596	1.596	1.596	846.98	846.98	846.98
	Annual	**30.655**	**39.580**	**18.927**	**16,271.66**	**21,008.94**	**10,046.49**
O3	1	1.719	1.719	1.719	4,676.61	4,676.61	4,676.61
	2	2.835	2.835	2.835	7,714.33	7,714.33	7,714.33
	3	5.115	5.115	5.115	13,917.45	13,917.45	13,917.45
	4	6.606	6.606	6.606	17,972.14	17,972.14	17,972.14
	5	47.183	63.565	10.993	128,372.67	172,945.30	29,910.20
	6	61.784	85.681	13.234	168,100.65	233,116.93	36,007.62
	7	55.676	96.137	14.732	151,481.70	261,565.31	40,082.83
	8	48.908	84.964	12.756	133,066.95	231,167.09	34,706.13
	9	35.794	58.060	8.600	97,386.70	157,966.44	23,398.35
	10	7.498	10.117	3.560	20,401.15	27,526.80	9,687.15
	11	1.724	1.724	1.724	4,690.05	4,690.05	4,690.05
	12	1.430	1.430	1.430	3,890.42	3,890.42	3,890.42
	Annual	**276.272**	**417.952**	**83.305**	**751,670.82**	**1,137,148.88**	**226,653.29**

		Removal (Short Ton)			Value ($)[1]		
Pollutant	Month	Mean	Max	Min	Mean	Max	Min
PM10	1	15.026	23.478	5.870	237,323.61	370,818.14	92,704.53
	2	16.321	25.502	6.375	257,780.50	402,782.03	100,695.51
	3	14.148	22.107	5.527	223,461.42	349,158.47	87,289.62
	4	8.448	13.200	3.300	133,431.16	208,486.19	52,121.55
	5	16.714	26.116	6.529	263,984.91	412,476.42	103,119.11
	6	27.005	42.196	10.549	426,527.49	666,449.21	166,612.30
	7	39.209	61.264	15.316	619,276.23	967,619.11	241,904.78
	8	41.661	65.096	16.274	658,008.90	1,028,138.90	257,034.73
	9	35.209	55.014	13.754	556,102.48	868,910.12	217,227.53
	10	16.674	26.053	6.513	263,352.00	411,487.49	102,871.87
	11	10.763	16.818	4.204	169,999.32	265,623.93	66,405.98
	12	15.633	24.427	6.107	246,911.30	385,798.90	96,449.73
	Annual	**256.812**	**401.269**	**100.317**	**4,056,159.31**	**6,337,748.92**	**1,584,437.23**
PM2.5	1	1.332	2.865	0.164	288,711.19	620,708.52	35,465.22
	2	0.450	0.931	0.056	97,460.32	201,781.96	12,237.74
	3	0.314	0.932	0.043	68,033.62	201,893.00	9,327.41
	4	0.417	1.015	0.052	90,380.43	219,871.89	11,160.69
	5	1.090	2.405	0.133	236,194.26	521,153.19	28,881.38
	6	1.267	2.865	0.156	274,451.01	620,784.97	33,761.85
	7	0.377	1.258	0.082	81,749.48	272,483.72	17,674.02
	8	-0.402	-1.250	-0.085	-87,001.37	-270,865.97	-18,431.94
	9	0.495	1.217	0.083	107,279.68	263,620.46	17,924.14
	10	0.818	2.341	0.157	177,242.96	507,181.73	33,960.13
	11	1.823	4.250	0.237	394,963.35	920,902.06	51,432.01
	12	5.228	11.459	0.634	1,132,756.97	2,482,927.01	137,368.97
	Annual	**13.210**	**30.286**	**1.711**	**2,862,221.89**	**6,562,442.53**	**370,761.65**
SO2	1	0.305	0.305	0.305	107.86	107.86	107.86
	2	0.010	0.010	0.010	3.40	3.40	3.40
	3	0.033	0.033	0.033	11.72	11.72	11.72
	4	0.007	0.007	0.007	2.33	2.33	2.33
	5	0.024	0.045	0.011	8.56	15.80	3.87
	6	0.027	0.047	0.011	9.64	16.67	3.97
	7	0.060	0.127	0.030	21.34	44.80	10.66
	8	0.029	0.065	0.016	10.29	22.99	5.60
	9	0.030	0.056	0.015	10.57	19.99	5.19
	10	0.011	0.016	0.008	3.77	5.68	2.72
	11	0.009	0.009	0.009	3.02	3.02	3.02
	12	0.005	0.005	0.005	1.91	1.91	1.91
	Annual	**0.549**	**0.724**	**0.459**	**194.41**	**256.18**	**162.26**

[1]Pollution Removal value is calculated based on the prices of $1136 per ton (CO), $2721 per ton (O3),$531 per ton (NO2), $354 per ton (SO2), $15794 per ton (PM10), $216679 per ton (PM2.5)

Energy Effects from Trees in Treasure Valley

Series: Regional, Time Period: 2011

	Units		
Type	**Heating**	**Cooling**	**Total**
MBTU	-96,830		-96,830
MWH	-939	12,580	11,641
Carbon Avoided	-1,989.67	555.56	-1,434.11

	Energy Values ($)		
Type	**Heating**	**Cooling**	**Total**
MBTU	-1,149,355.97		-1,149,355.97
MWH	-75,495.60	1,011,432.00	935,936.40
Carbon Avoided	-141,692.50	39,564.00	-102,128.50
Total	**-1,366,544.07**	**1,050,996.00**	**-315,548.07**

Carbon avoided value is calculated based on $71 per ton

Energy saving value is calculated based on the prices of $80.4 per MWH and $11.87 per MBTU

Rainfall Interception for Trees in Treasure Valley by Land Use

Series: Regional, Time Period: 2011

Land Use	Tree Number	Leaf Area (mi2)	Rainfall Interception (ft3/yr)	Rainfall Interception Value ($)
Single Strata	2,431,611	118.7704	16,780,338.43	1,117,178.27
Total	**2,431,611**	**118.7704**	**16,780,338.43**	**1,117,178.27**

Water interception is calculated by the price $0.067/ft3