Urban Forest Resource Analysis
The State of Montana

2017

MONTANA DNRC

DAVEY RESOURCE GROUP
A Division of The Davey Tree Expert Company

Urban Forest Resource Analysis

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2017

Prepared for:

Montana Department of Natural Resources and Conservation
2705 Spurgin Road
Missoula, MT 59804
Phone: (406) 542-4300
Fax: (406) 542-4217
http://www.dnrc.mt.gov

Prepared by:

Davey Resource Group
A Division of the Davey Tree Expert Company
6005 Capistrano Ave. Suite A
Atascadero, California 93422
Phone: 805-461-7500
Toll Free: 800-966-2021
Fax: 805-461-8501
www.davey.com/drg

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Executive Summary

Urban and community trees play a critical role in the State of Montana. They provide numerous benefits both tangible and intangible to residents, visitors, and neighboring communities. Montana's publicly-owned forest includes 157,403 individual sites that include 138,420 trees, 17,512 vacant sites, and 1,471 stumps throughout 61 inventoried communities. Montana's Department of Natural Resources and Conservation (DNRC) recognizes that these trees are a valued resource, an important component of the urban infrastructure, and part of the state's identity.

In recent years, to support the preservation and management of urban and community trees, the state of Montana Urban and Community Forestry Program and various communities commissioned inventories of public trees within the street right-of-way (ROW) and in city parks. The inventories produced GIS layers that include information about each tree including species, size, condition, and geographic location. Davey Resource Group (DRG) used this data in conjunction with Treekeeper® version 7.7 and MyTreekeeper®, which uses the National Tree Benefit Calculator (treebenefits.org) to determine species benefits and to develop a quantified analysis of the current structure, function, and value of the urban forest. This report details the results of that analysis.

The 61 inventoried forests throughout Montana provide nearly $17.2 million in annual benefits. These benefits include air quality improvements, energy savings, stormwater runoff reduction, atmospheric CO_2 reduction, and aesthetic contributions to the social and economic health of the state. Based on the 40 communities that report an annual tree care budget to the Arbor Day Foundation's Tree City USA program, Montana communities are contributing at least $3.3 million annually to support publicly-owned trees. This value represents both budget dollars and in-kind (volunteer) contributions. For every $1 invested in Tree City USA communities, they receive $4.41 in benefits (see Benefit-Investment Ratio).

Annually, Montana's urban forests are reducing electric energy consumption by 12,455 megawatt hours (MWh) and natural gas consumption by nearly 1.2 million therms, for a combined value of $1,844,435. The sheltering effect of the public tree canopy reduces stormwater runoff by more than 122.4 million gallons each year, helping to protect local, regional, and state water resources by reducing sediment and pollution loading. Annually, public trees sequester 4,768 tons of carbon (CO_2). An additional 5,874 tons of CO_2 is avoided each year for an annual net benefit valued at $147,635.[1] Each year public trees are removing 47,513 pounds of pollutants from the air, including ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulates (PM_{10}).

The urban forests across Montana are mostly well established and 55% of inventoried trees are considered to be in good condition. Statewide, the age distribution of all trees is quite favorable. Nearly half (47%) of the inventoried trees are young trees measuring 8 inches or less in diameter at breast height (DBH). The abundance of young trees ensures a future forest that will provide benefits for many years. Eleven percent of Montana's inventoried trees are greater than 24 inches DBH, suggesting that from a statewide perspective, a reasonably small percentage of trees are very mature and will soon require expensive maintenance and removal costs. Realizing that several cities in Montana were established nearly 150 years ago, portions of many urban forests, especially in Missoula and Kalispell, are declining due to age. The necessity of removing and replacing many dead and dying trees during a short time period creates management issues that communities in the state have not previously faced.

[1] Avoided Carbon: Avoided carbon is a result of reducing energy consumption. The avoided value represents carbon that would have been created from the production of additional energy.

Regular inspection and proactive maintenance will promote the preservation of existing benefits, support individual tree longevity, and help manage risk.

Ash are the most commonly planted trees in several Montana communities, especially east of the Continental Divide. Nearly 30% of all trees inventoried were ash (green, white, spp.) (Figure 1). Emerald ash borer (EAB), an Asian beetle has killed millions of trees in at least 30 states since 2002. Although EAB is not known from Montana as of 2017, it threatens to drastically change communities with an over-abundance of ash. In response to this serious threat, regulatory agencies and the USDA enforce quarantines and fines to prevent potentially infested ash trees, logs or firewood from moving out of areas where EAB occurs. Planting a broad diversity of non-ash species may help to limit future tree death from EAB and other species-specific pests, but will not prevent widespread loss in our urban forests given their current condition. New forest pests will continue to be detected; vigilance in monitoring and continued education is necessary to maintain the health of urban forests.

Some urban foresters use a 10-20-30 threshold as a guideline to reduce the possibility of catastrophic tree loss due to insects or disease striking a specific tree type. This recommendation suggests an urban tree population include no more than 10% of any one species, 20% of one genus or 30% of one family. For some western Montana communities, Norway maples, exceed the maximum 10%, and at the state level they rank second to ash and are 9.7% of the inventoried population.

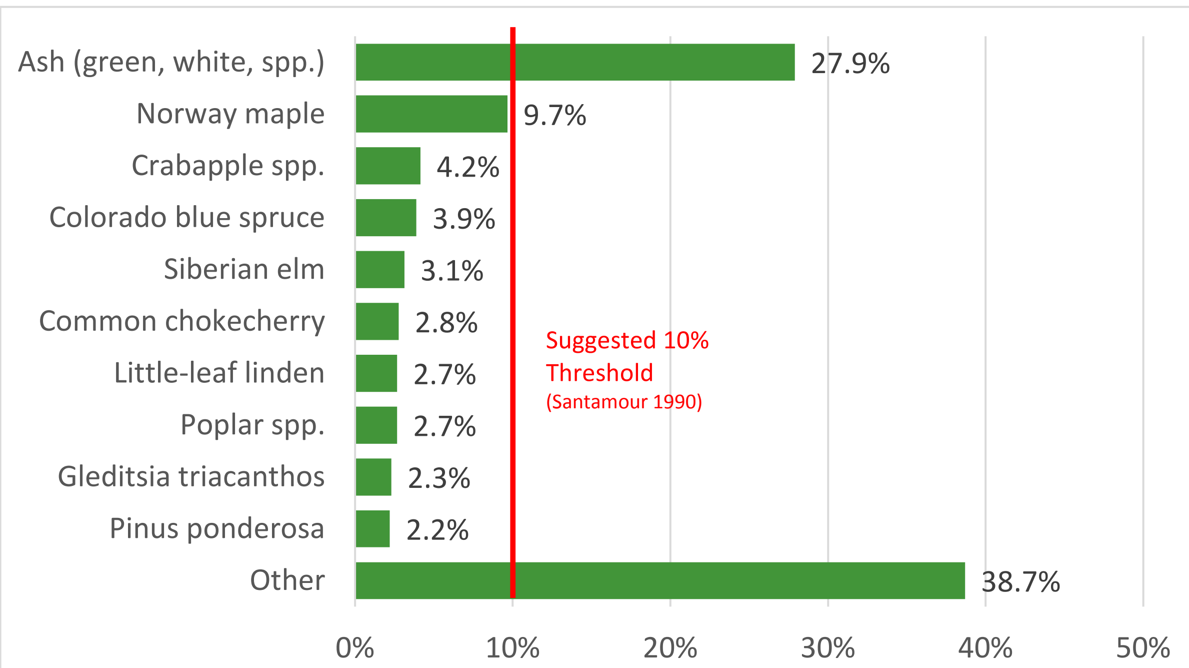


Figure 1: Top Ten Species in Statewide Inventoried Forests

Public trees are a part of the infrastructure and character of Montana communities. Unlike most other public assets, with proper maintenance, trees have the potential to increase in value over time (Figure 2). With the overall established tree population in good condition, a high percentage of young trees, and more than 180 different species, urban and community forests in Montana will continue to be a vital asset at both the local and statewide levels.

Figure 2: Young Maples Line this Park in Columbia Falls

Introduction

The eastern portion of Montana was originally acquired by the U.S. from France in 1803 as part of the Louisiana Purchase, while the western region was obtained from Great Britain in the Oregon Treaty of 1846. Montana became a territory in 1864 and became the 41st state, with Helena as its capital, in 1889 (Figure 3). Despite being the 4th largest state by size (147,042 square miles of land and water), Montana is one of the least populous states, with an average of 6 people per square mile (Montana.gov 2016). The state is ranked 44th for population size, with the U.S. Census Bureau estimating the 2015 population at 1,032,949 people.

Montana has 54 state parks, and is home to Glacier National Park, Little Bighorn National Monument, a portion of Yellowstone National Park, and millions of acres of United States Forest Service and Bureau of Land Management lands. Popular outdoor recreational activities include hunting, fishing, horseback riding, hiking, snowmobiling, and skiing.

Figure 3: The State Capitol in Fall Color, Helena

Communities

Montana has 129 incorporated municipalities. Using state and federal funding, the DNRC collected or compiled inventory data from 61 of these municipalities. The communities are widespread across the state of Montana, and represent diverse climatic and ecological conditions. Only cities with a current tree inventory (performed between 2008 and 2015) were included as part of this report (Figure 4). The populations of these communities range from 125 (City of Judith Gap) to 110,623 (City of Billings). Most communities have inventory data for public right-of-way trees, park trees, and vacancies, but not every city provided information for all three categories. Montana's three largest cities do not have complete public tree inventories. The City of Billings has inventory data for their parks, but not for street right-of-ways, and Great Falls has no current inventory at the time of this publication, but Malmstrom Air Force Base, adjacent to Great Falls, has a completed inventory. The inventory for Missoula, the second-largest city in Montana, is still in progress. Of the 61 communities, 66% are Tree City USA communities. The Tree City USA program is administered by the National Arbor Day Foundation providing nation-wide recognition of a community's commitment to their urban forest.

Figure 4: Inventoried Montana Communities

Individual trees and healthy urban forests play an important role in the quality of life and the sustainability of every community. Research demonstrates that healthy urban trees can improve the local environment and diminish the impact resulting from urbanization and industry (Center for Urban Forest Research). Trees improve air quality by manufacturing oxygen and absorbing carbon dioxide (CO_2), as well as filtering and reducing airborne particulate matter such as smoke and dust. Urban trees reduce energy consumption by shading structures from solar energy and reducing the overall rise in temperature created through urban heat island effects (EPA). Trees slow and reduce stormwater runoff, helping to protect critical waterways from excess pollutants and particulates. In addition, urban trees provide critical habitat for wildlife and promote a connection to the natural world for urban residents.

Healthy urban trees increase the overall attractiveness of a community and the value of local real estate. Trees promote shopping, retail sales, and tourism (Wolf 2007). Trees support a livable community, fostering psychological health, and providing residents with a greater sense of place (Ulrich 1986, Kaplan 1989). Community trees, both public and private, soften the urban hardscape by providing a green sanctuary, ensuring that Montana's urban areas provide a more enjoyable place to live, work, and play. Public trees play a prominent role in the overall urban forest benefits afforded to each community.

The Urban and Community Forestry Program of Montana DNRC assists Montana communities with the development and maintenance of their urban forestry programs. The communities studied as part of this project oversee 138,420 trees on streets and right-of-ways and in city parks. Each of these vital resources is cared for by the local communities with the help of Montana DNRC. Inventoried cities are dispersed widely across the state, with 16 communities located west of the Continental Divide and 45 communities east of the Divide. The median population of the western communities is 3,624, while the median population for eastern communities is 1,923. See Tables 1 and 2 for estimated population and number of trees in each inventoried community.

Table 1: Inventoried Communities West of the Continental Divide

Inventoried Communities West of the Continental Divide			
Community	**County**	**Population (2015 estimated)**	**Number of Trees**
Alberton	Mineral	424	101
Anaconda	Deer Lodge	9,139	2,643
Butte	Silver Bow	33,922	4,403
Columbia Falls	Flathead	5,093	3,339
Drummond	Granite	336	276
Eureka	Lincoln	1,074	364
Hamilton	Ravalli	4,602	1,639
Kalispell	Flathead	22,052	9,077
Libby	Lincoln	2,645	1,751
Missoula	Missoula	71,022	22,537
Polson	Lake	4,707	1,584
Ronan	Lake	1,981	867
Stevensville	Ravalli	1,922	614
Superior	Mineral	839	347
Thompson Falls	Sanders	1,332	623
Whitefish	Flathead	7,073	3,474
16 Communities Total		**168,163**	**53,639**

Table 2: Inventoried Communities East of the Continental Divide

Inventoried Communities East of the Continental Divide			
Community	County	Population (2015 estimated)	Number of Trees
Big Timber	Sweet Grass	1,648	1,069
Billings (parks)	Yellowstone	110,263	8,335
Bozeman	Gallatin	43,405	10,559
Broadus	Powder River	488	731
Browning	Glacier	1,027	344
Cascade	Cascade	696	418
Choteau	Teton	1,696	1,354
Colstrip	Rosebud	2,336	855
Columbus	Stillwater	2,042	1,192
Conrad	Pondera	2,593	1,203
Culbertson	Roosevelt	815	339
Cut Bank	Glacier	3,002	577
Dillon	Beaverhead	4,210	781
Ennis	Madison	884	216
Forsyth	Rosebud	1,892	716
Fort Benton	Chouteau	1,460	895
Fort Peck	Valley	251	584
Glasgow	Valley	3,414	1,603
Glendive	Dawson	5,490	1,987
Great Falls MAFB	Cascade	3,472	8,610
Hardin	Big Horn	3,505	1,000
Harlowton	Wheatland	979	1,080
Havre	Hill	9,834	3,554
Helena	Lewis and Clark	30,581	9,385
Judith Gap	Wheatland	125	148
Laurel	Yellowstone	6,943	3,361
Lewistown	Fergus	5,874	2,665
Livingston	Park	7,307	3,888
Lodge Grass	Big Horn	445	86
Manhattan	Gallatin	1,631	774
Miles City	Custer	8,796	4,238
Plentywood	Sheridan	1,923	606
Red Lodge	Carbon	2,222	2,205
Roundup	Musselshell	1,836	1,548
Saco	Phillips	201	116
Shelby	Toole	3,268	1,364
Sheridan	Madison	677	141
Sidney	Richland	6,828	2,125
Stanford	Judith Basin	381	297
Townsend	Broadwater	1,959	997
Valier	Pondera	508	564
West Yellowstone	Gallatin	1,339	637
White Sulphur Springs	Meagher	910	492
Whitehall	Jefferson	1,094	422
Wolf Point	Roosevelt	2,850	1,016
45 Communities Total		**293,100**	**85,077**

Climate

Montana has various climates across the state, but weather tends to be milder west of the Continental Divide. West of the mountain barrier winters are less severe, precipitation occurs more evenly throughout the year, summers are a little cooler, and winds are lighter than on the eastern side. More cloudy days occur west of the Divide in all seasons, humidity is higher, and the growing season is shorter than in the eastern plains. Climatic variations are influenced by the wide range of elevations, from 1,800 feet in the northwestern corner to over 12,800 feet near Yellowstone National Park. Most of the western third of Montana is very mountainous, while the eastern portion is characterized by grassy plains with wide valleys and small, isolated mountain ranges, hills, and badlands. Half of the state's topography is over 4,000 feet above sea level (Western Regional Climate Center 2016).

Precipitation levels differ considerably, depending on the region of the state. The northwest community of Heron in Sanders County receives the highest annual precipitation of 35 inches, while less than 7 inches falls at the Clarks Fork of the Yellowstone River, in southern Montana's Carbon County. In the mountainous regions of the state, annual snowfall can sometimes reach 300 inches, but in north central and northeast Montana, snowfall has been as low as 20 inches. Most larger cities receive an average annual snowfall of between 30 to 50 inches. The annual rainy season usually spans May through July, and snowfall typically occurs in November through April. Occasionally, snowstorms will begin as unseasonably early as September, or as late as May (Western Regional Climate Center 2016).

The average summer temperature in southeastern Montana is 74° F, while in the higher elevation southwest the average is 64° F. Miles City, one of the communities with the warmest summers, has a maximum average summer temperature of 90° Fahrenheit (F). Winter temperatures are also variable, with northeastern Montana averaging approximately 11° F. This area experiences between six to twelve cold waves per winter, where temperatures can fall below zero, and as low as -50° F. The south-central portion of the state averages 22° F in winter. (Western Regional Climate Center 2016)

Helena, the state capital, experiences an annual high of 86° F, and low of 12° F with a 12-month average annual temperature of 46° F. The city receives an average annual rainfall of 11 inches, and an average annual snowfall of 38 inches (US Climate Data 2016).

Montana includes seven USDA Plant Hardiness Zones, from 3a to 6a (Figure 5). The coldest zone (3a) includes northern and northeast Montana, and along the peaks of the Rocky Mountains. Warmer zones are generally located in the west and south, with the warmest, zone 6a (-10° F to -5° F), covering portions of Sanders, Mineral, Lincoln and Lake counties. (USDA 2016).

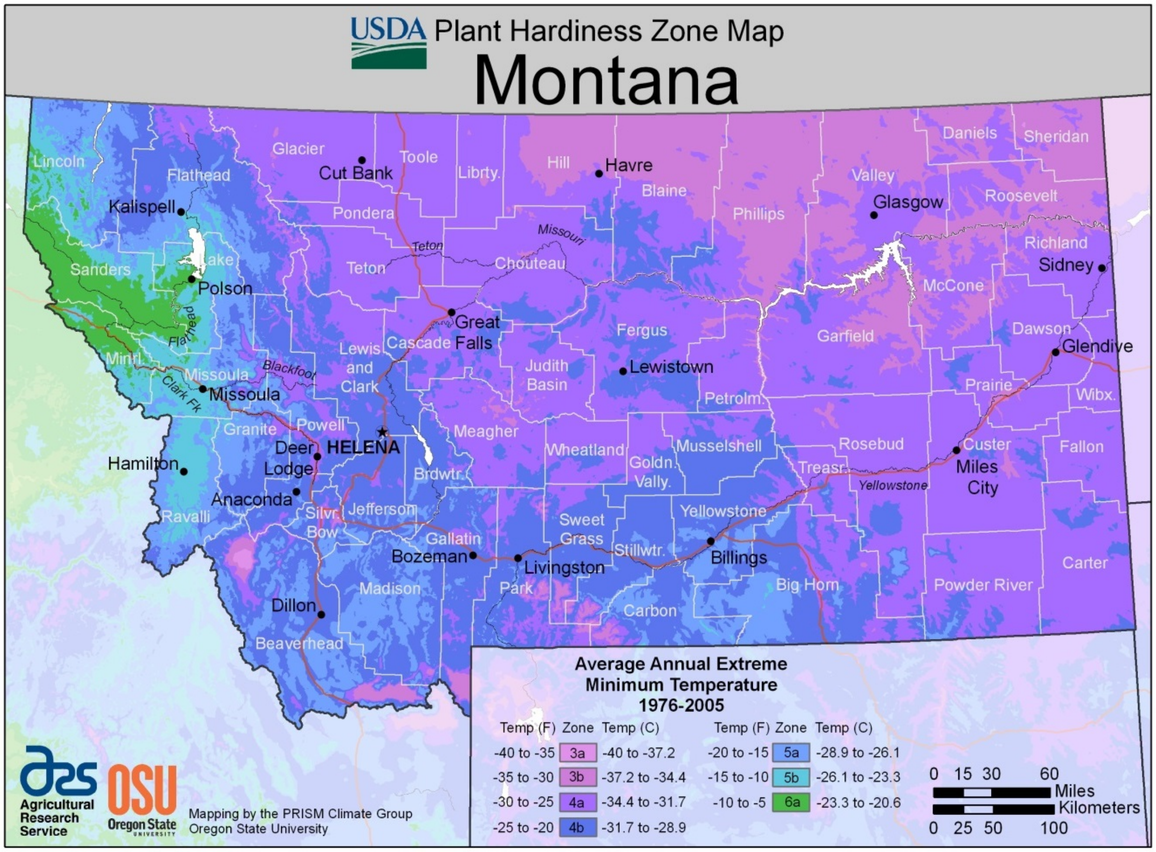


Figure 5: USDA Hardiness Zones of Montana

Data Collection and Analysis

To support the management of Montana's urban forests, public tree inventories were collected throughout 61 communities in the state. Inventory information was collected in these communities between 2008 through 2015 (Figure 6). The inventories collected the species, size, condition, site information, maintenance recommendations and geographic location of each tree in an electronic GIS format.

The tree inventory data were analyzed with MyTreekeeper® and Treekeeper® version 7.7 to develop a resource analysis and report of the existing condition of the combined urban forest resource. This report quantifies the value of trees throughout the state from inventoried communities, with regard to actual benefits derived from the tree resource. In addition, the report provides baseline values often used to develop and update an urban forest management plan. Management plans help communities determine where to focus available resources and set benchmarks for measuring progress.

Figure 6: Volunteers Worked with DNRC to Complete Inventories in Several Communities

This analysis describes the overall structure, function, and value of Montana's community trees, and paints a representative picture for the rest of the state. With this information, managers and residents can make informed decisions about tree management strategies. This report provides the following information:

- A description of the current overall structure of the community tree resource in Montana and an established benchmark for future management decisions
- The overall economic value of the benefits from urban forests, illustrating the relevance and relationship of trees to the quality of life issues such as air quality, environmental health, economic development, and psychological health
- Data that may be used by resource managers in the pursuit of alternative funding sources and collaborative relationships with utility purveyors, non-governmental organizations, air quality districts, federal and state agencies, legislative initiatives, or local assessment fees
- Benchmark data for developing long-term urban forest strategies

This resource analysis is distinctive in that most projects analyze only one community at a time. Working at a broad statewide scale provides a unique perspective but comes with challenges as well. Since this study does not represent every Montana community, it is important to be aware that this is a representative analysis rather than a comprehensive one. Variations in climate, geography, local management practices and staffing, species compositions, and tree age distribution in these communities contribute to regional diversity, which may not be fully represented in this report.

Quick Facts

Structure

Montana's inventoried urban forests include 138,420 public trees and 17,512 available planting sites on streets. A structural analysis is the first step towards understanding the benefits provided by these trees as well as their management needs. Considering species composition, diversity, age distribution, condition, canopy coverage, and replacement value, DRG determined that the following information characterizes the overall urban forest resource in Montana:

- More than 180 unique tree species were identified by the inventories. The predominant species are ash (*Fraxinus spp*, 28%), Norway maple (*Acer platanoides*, 10%), and crabapple (*Malus spp*., 4%). These comprise 42% of the overall resource.
- Ash is dominant in many communities east of the Continental Divide (33,776 trees). Norway maple is dominant or of high importance in many cities west of the Divide (11,853 trees).
- Almost half of all trees are less than 8" DBH (47%) and 11% are larger than 24", indicating a nearly ideal mix of young, established, and mature trees providing a sustainable benefit flow.
- 55% of trees are in good condition.
- The current stocking level for the inventoried urban forest is 87.9%, based on a total 157,403 sites, including 138,420 trees and 18,983 vacant sites and stumps.
- While each community has a unique number of trees, the average is 2,269 trees per community, which equates to one tree for every three people.
- Replacement of Montana's 138,420 community trees with trees of similar size, species, and condition would cost nearly $185.5 million.

Benefits

Annually, community trees in Montana provide cumulative benefits at an average value of $124.15 per tree, for a total gross value of nearly $17.2 million per year (Appendix A). MyTreekeeper®, which used the National Tree Benefits Calculator (treebenefits.org), was used to calculate environmental, aesthetic, and socioeconomic benefits as well as tree value estimates. The National Tree Benefits Calculator is based on i-Tree STREETS, a peer-reviewed software suite from the USDA Forest Service. These annual benefits include:

- $13.7 million in benefits of property value, health, aesthetics, and socioeconomics; an average of $99.32 per tree.
- Reduction in electricity and natural gas consumption through shading and climate effects for an overall benefit of $1,844,435, an average of $15.25 per tree.
- 4,768 tons of atmospheric CO_2 sequestered and an additional 5,874 tons avoided for a net value of $147,635 and a net average of $1.22 per tree.
- 47,513 pounds of air pollutants removed with a gross value of $123,273.
- More than 122 million gallons of stormwater intercepted annually for a total value of more than $1.3 million, an average of $10.93 per tree

Forty inventoried communities reported urban forestry budgets to Tree City USA in 2015. These communities reported an overall $3.3 million towards the support of their urban forests (including in-kind volunteer hours). Overall annual net benefit (benefit minus investment) for these communities is $11.2 million, an average of $92 per tree. For every $1 invested in public trees, Tree City USA communities receive $4.41 in benefits.

Management

Montana's urban forests are a dynamic resource that requires continued investment to maintain and realize full benefit potential. Trees are one of the few community assets that have the potential to increase in value with time. Proper and timely tree care can substantially increase lifespan. When trees live longer, they provide greater air quality, human health, energy-saving and other benefits. Trees are, however, vulnerable to a host of stressors and require sustainable best management practices to ensure a continued flow of benefits for future generations.

Young tree training, a consistent pruning cycle, and regular inspection to identify structural and age-related defects will manage risk and reduce hazards from tree and branch failure. Based on this resource analysis, DRG recommends the following approach for Montana's communities:

- Increase species diversity by ensuring that new tree plantings include a variety of suitable species, since a diverse tree population is more resilient to biological and environmental threats.
- Increase the stocking level by using all available planting sites to improve diversity and increase benefits. Plant large-stature species wherever space allows.
- Provide structural pruning for young trees and a regular pruning cycle for all trees (preferably every 5-7 years for mature trees) (Figure 7).
- Protect existing trees from equipment, animal and human-caused damage, especially mature high-value species, and manage risk with regular inspection to identify and mitigate structural and age-related defects.
- Continue to maintain and update the inventory database, including tracking tree growth and condition during regular pruning cycles.

It is important to note that the statewide values are averages and individual communities will have tree populations with differing size or condition distributions. Ultimately, when considering maintenance planning, communities must remember that the most successful plans will be established for local conditions.

Montana DNRC can help to further the benefits of trees and urban forestry by providing the following services to communities:

- Provide technical assistance, financial assistance, public education and volunteer coordination
- Update existing inventories and perform new inventories to develop a more complete picture of the Montana statewide urban forest resource
- Develop a general Urban and Community Forestry Program Plan template. Work with individual communities to tailor plans to their specific needs.
- Encourage communities to understand the important distinction between forestry and urban forestry, and help them to develop proactive urban forest maintenance plans
- Further explore the inventory by sub-regions to find additional trends that might encourage maintenance practices.
- Increase public outreach and education of urban forestry, using inventory information as a catalyst for leveraging local and statewide support of urban forestry programs.

With adequate protection and planning, the value of the community forest resource in Montana will increase over time. Proactive management and a tree replacement plan at the community level are critical to ensuring that residents continue to receive a high return on their investment. Along with new tree installation and replacement planting, funding for tree maintenance and inspection is vital to preserving benefits, prolonging tree life, and managing risk. Existing mature trees should be maintained and protected to ensure the continued growth and longevity of the existing canopy, and the environmental, social and economic benefits associated with those trees. Managers can take pride in knowing that community trees support the quality of life for residents and neighboring communities.

Figure 7: Pruning Young Trees is an Essential Part of Tree Maintenance

Montana's Urban Forest Resource

An urban forest is more thoroughly understood through examination of composition and species richness (diversity). Consideration of stocking level (trees per total available space), canopy cover, relative age distribution, condition, and performance provides a foundation for urban forest planning and management strategies. Inferences based on this data can help managers understand the importance of individual tree species to the overall forest as it exists today and provide a basis on which to project the potential value of the resource.

Population Composition

Of prevalent species (those representing >1% of the overall population), broadleaf deciduous species comprise 86% of the species inventoried, including 67% classified as large-stature, 9% medium-stature, and 10% small-stature species (Figure 8). Conifers comprise the remainder of the tree population at 14%, including 1% medium-stature and 13% large-stature species.

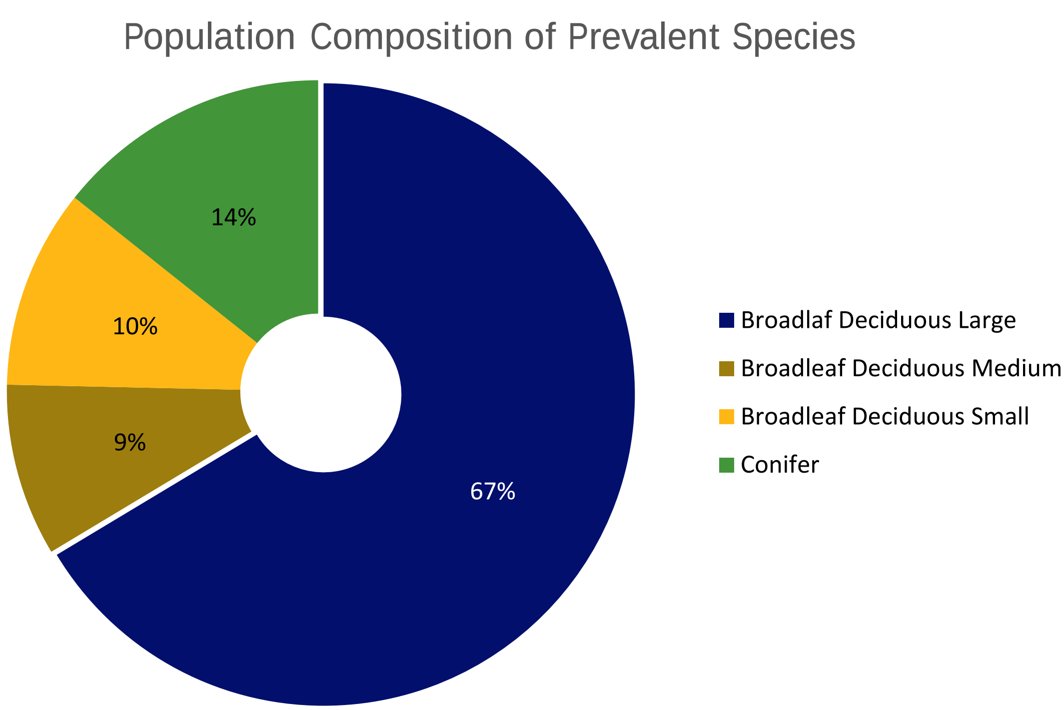


Figure 8: Composition of Tree Type and Stature in Montana's Urban Forests

Species Richness and Composition

No single species should dominate the composition of an urban forest population. Suitability of the dominant species is an important consideration. Planting short-lived or poorly-adapted species can result in shorter lifespans and increased long-term management investments.

Montana's urban forests include more than 180 unique species (Table 3). While this value is measured statewide in 61 communities, rather than just for a single community, the value is much greater than the mean of 53 species reported by McPherson and Rowntree (1989) in their nationwide survey of street tree populations in 22 U.S. cities. Other states have higher unique species values. For example, in Washington state, 20 communities have 330 unique species, and in Indiana, 23 communities have 243 unique species (WA DNR 2015, DRG 2009).

The top three most prevalent trees represent 42% of the overall population: ash (*Fraxinus spp.*, 28%), Norway maple (*Acer platanoides*, 10%), and crabapple (*Malus spp.*, 4%) (Figure 9). A widely accepted guideline suggests that no single species should represent greater than 10% of the total population, and no single genus more than 20% (Clark et al. 1997). Ash and Norway maple both exceed this recommendation at the state level. Several other species exceed 10% and several genera exceed 20% in individual communities. Communities differed in their inventory methods; some communities collected data at the species level, while others interpret their tree populations using broader genus or population descriptors (i.e. ash spp., elm spp., poplar spp; or Broadleaf Deciduous Small, Medium or Large, and Conifer), thus the exact species percentage may not be known for a community.

Maintaining diversity in an urban forest is important. Dominance of any single species or genus can have detrimental consequences in the event of storms, drought, disease, pests, or other stressors. Catastrophic pathogens, such as Dutch elm disease (*Ophiostoma ulmi*), emerald ash borer (*Agrilus planipennis*), Asian longhorned beetle (*Anoplophora glabripennis*), and sudden oak death (SOD) (*Phytophthora ramorum*) are some examples of unexpected, devastating, and costly pests and pathogens that highlight the importance of diversity and the balanced distribution of species and genera (Figure 10).

Table 3: Population Summary (Species Exceeding 1%)

Species Broadleaf Deciduous Large	0-3"	3-6"	6-12"	12-18"	18-24"	24-30"	30-36"	36-42"	>42"	Total	% of Pop
Green ash	2,470	4,012	5,887	8,597	5,550	1,283	186	48	37	**28,070**	**20.28%**
Norway maple	1,073	1,298	1,742	2,629	4,203	1,931	404	76	18	**13,374**	**9.66%**
Ash spp.	434	498	783	2,273	1,625	441	58	9	5	**6,126**	**4.43%**
White ash	382	579	1,049	1,485	722	208	44	10	1	**4,480**	**3.24%**
Little-leaf linden	1,280	1,359	739	198	72	20	10	1	4	**3,683**	**2.66%**
Poplar spp.	177	235	533	566	650	595	416	257	253	**3,682**	**2.66%**
Honey locust	786	803	1,031	342	123	32	10	3	0	**3,130**	**2.26%**
Eastern cottonwood	590	186	386	474	346	330	271	162	146	**2,891**	**2.09%**
Quaking aspen	693	823	857	283	70	27	7	9	7	**2,776**	**2.01%**
American elm	237	103	205	435	728	614	273	87	51	**2,733**	**1.97%**
American linden	658	671	505	132	115	52	11	5	3	**2,152**	**1.55%**
Silver maple	173	221	250	258	310	302	181	83	70	**1,848**	**1.34%**
Other BDL	1,878	1,578	1,208	871	888	811	515	333	415	**8,497**	**6.14%**
Total Broadleaf Deciduous Large	**10,831**	**12,366**	**15,175**	**18,543**	**15,402**	**6,646**	**2,386**	**1,083**	**1,010**	**83,442**	**60.3%**

Species	0-3"	3-6"	6-12"	12-18"	18-24"	24-30"	30-36"	36-42"	>42"	Total	% of Pop
Broadleaf Deciduous Medium											
Siberian elm	299	462	665	853	784	705	342	150	75	**4,335**	**3.13%**
Willow spp.	1,755	66	112	99	86	119	68	65	106	**2,476**	**1.79%**
Red maple	798	799	246	41	12	7	2	0	0	**1,905**	**1.38%**
Boxelder	118	152	250	244	264	212	93	42	22	**1,397**	**1.01%**
Other BDM	1,838	1,505	1,468	1,103	714	345	148	65	38	**7,224**	**5.22%**
Total Broadleaf Deciduous Medium	**4,808**	**2,984**	**2,741**	**2,340**	**1,860**	**1,388**	**653**	**322**	**241**	**17,337**	**12.5%**
Broadleaf Deciduous Small											
Crabapple spp.	2,200	1,857	1,122	362	122	53	19	9	4	**5,748**	**4.15%**
Common chokecherry	1,648	1,362	646	119	29	14	14	1	1	**3,834**	**2.77%**
Broadleaf Deciduous Small	377	1,211	307	73	71	39	18	6	5	**2,107**	**1.52%**
Other BDS	1,772	1,752	1,040	400	174	81	30	12	23	**5,284**	**3.82%**
Total Broadleaf Deciduous Small	**5,997**	**6,182**	**3,115**	**954**	**396**	**187**	**81**	**28**	**33**	**16,973**	**12.3%**
Total Broadleaf Evergreen Large	**0**	**0**	**4**	**5**	**4**	**0**	**0**	**0**	**0**	**13**	**0.01%**
Total Broadleaf Evergreen Medium	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0.00%**
Total Broadleaf Evergreen Large	**5**	**8**	**8**	**4**	**4**	**4**	**0**	**0**	**1**	**34**	**0.02%**
Conifer											
Colorado blue spruce	692	662	1,371	1,250	778	454	147	19	7	**5,380**	**3.89%**
Ponderosa pine	812	356	694	597	276	158	62	47	8	**3,010**	**2.17%**
Spruce spp.	358	437	456	325	183	81	39	4	0	**1,883**	**1.36%**
Austrian pine	274	561	418	275	78	20	3	0	0	**1,629**	**1.18%**
Douglas-fir	97	92	263	373	277	214	90	46	18	**1,470**	**1.06%**
Engelmann spruce	56	94	241	440	456	132	31	0	3	**1,453**	**1.05%**
Juniper spp.	494	498	185	78	32	16	11	0	2	**1,316**	**0.95%**
Other Conifer	687	989	1,400	831	356	152	40	10	14	**4,479**	**3.24%**
Total Conifer	**3,470**	**3,689**	**5,028**	**4,169**	**2,436**	**1,227**	**423**	**126**	**52**	**20,620**	**14.9%**
Total All Trees	**25,111**	**25,229**	**26,071**	**26,015**	**20,103**	**9,452**	**3,543**	**1,559**	**1,337**	**138,420**	**100%**

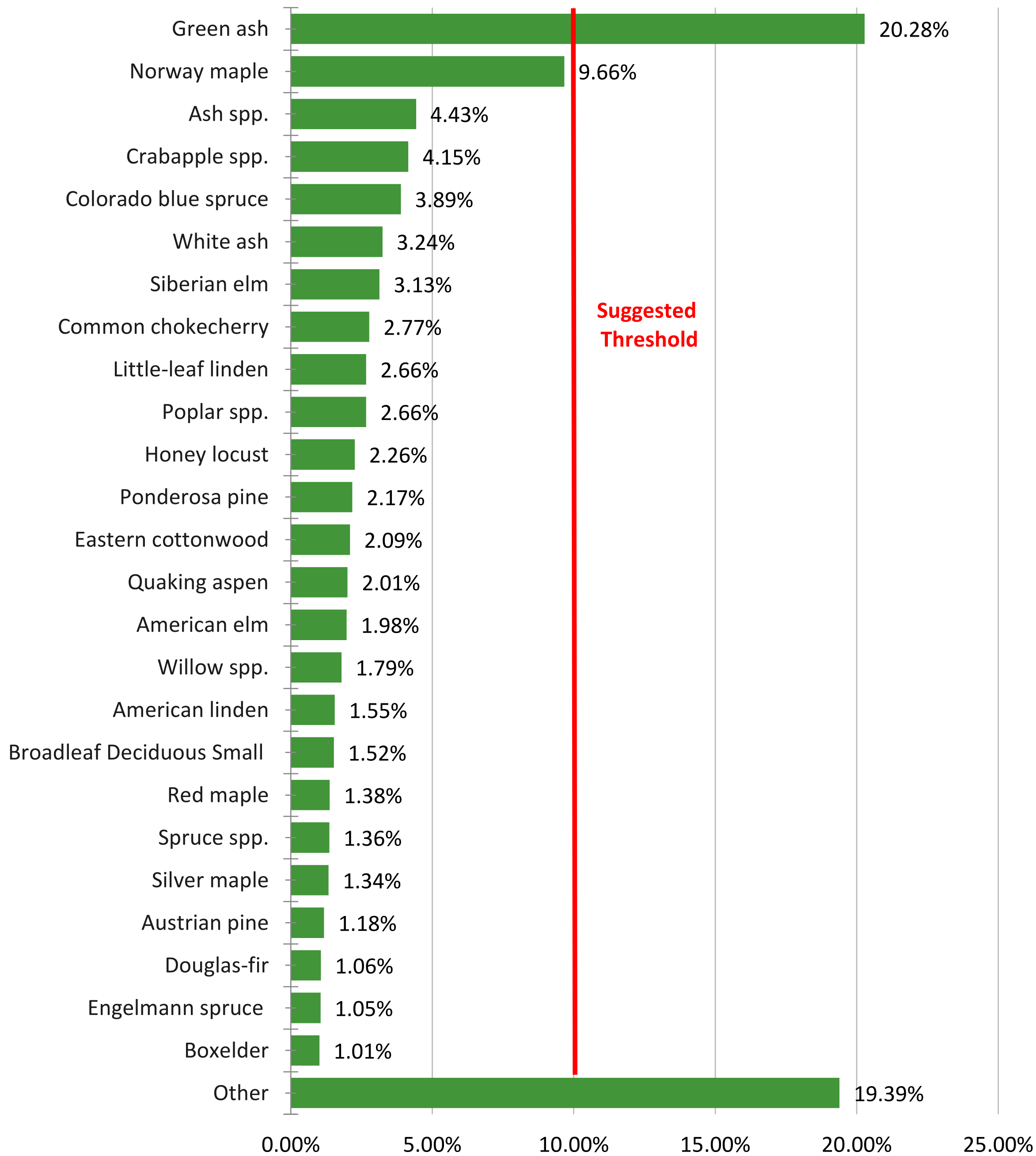


Figure 9: The Most Prevalent Trees Species[2]

[2] Index of common and scientific names for all figures and tables can be found in Appendix D

Figure 10: Elm in Kalispell with Dutch Elm Disease

The emerald ash borer (EAB) is a pest of specific concern to Montana communities. An invasive beetle pest native to eastern Asia, EAB threatens significant fiscal and environmental impacts wherever identified. While not yet identified in Montana, the borer has been spreading rapidly across the United States since its discovery. Emerald ash borer larval feeding disrupts the flow of nutrients and water, effectively girdling and eventually killing the tree. This feeding behavior combined with a fast reproduction cycle means that EAB is highly destructive to ash populations (Montana DNRC, 2015). Further information regarding EAB can be found in Appendix E. Additional resources can be found online at the Montana DNRC website's "Montana Urban and Community Forestry Association" page (http://dnrc.mt.gov/divisions/forestry/forestry-assistance/urban-and-community-forestry/urban-and-community-forestry-association **).**

Leaf Surface Area

The amount and distribution of leaf surface area will determine the urban forest's ability to produce benefits for the community (Clark 1997). As canopy cover increases, so do the benefits afforded by leaf area. Overall, community trees in Montana provide approximately 419.3 acres of leaf surface area. This value is not the same as canopy cover as it takes into consideration the entire surface area of the trees' leaves including vertical overlap. Also leaf surface area includes areas where canopies overlap, whereas canopy cover is a calculation that only considers the amount of tree canopy that shades the ground. This report only discusses leaf surface area, which includes vertical values and does not discuss the single-plane canopy cover.

The 10 most prevalent tree species represent 57% of the overall population and 66% of the total leaf area. Of these, the highest leaf surface is provided by green ash (*Fraxinus pennsylvanica*) at almost 120.7 acres. Norway maple (*Acer platanoides*) provides the second largest area of leaf surface at 38.3 acres.

Species Diversity-Differences Between Eastern and Western Montana

Distinct patterns are evident when using the Continental Divide as a boundary. Both eastern and western regions top ten species are mostly broadleaf deciduous, with approximately 4% conifers in the east and 7% in the west. (Figures 11 and 12) Ash (green, white, and spp. combined) are the most abundant tree east of the Divide, and second most abundant in western Montana. Norway maple is the top species west of the Divide. The top ten species in eastern Montana make up 67% of the total of eastern trees, while 58% of the total number of trees present in western Montana are included in the western top ten. Trees present in high numbers in both eastern and western Montana in addition to ash are Colorado blue spruce, crabapples, Siberian elm, poplars and common chokecherry.

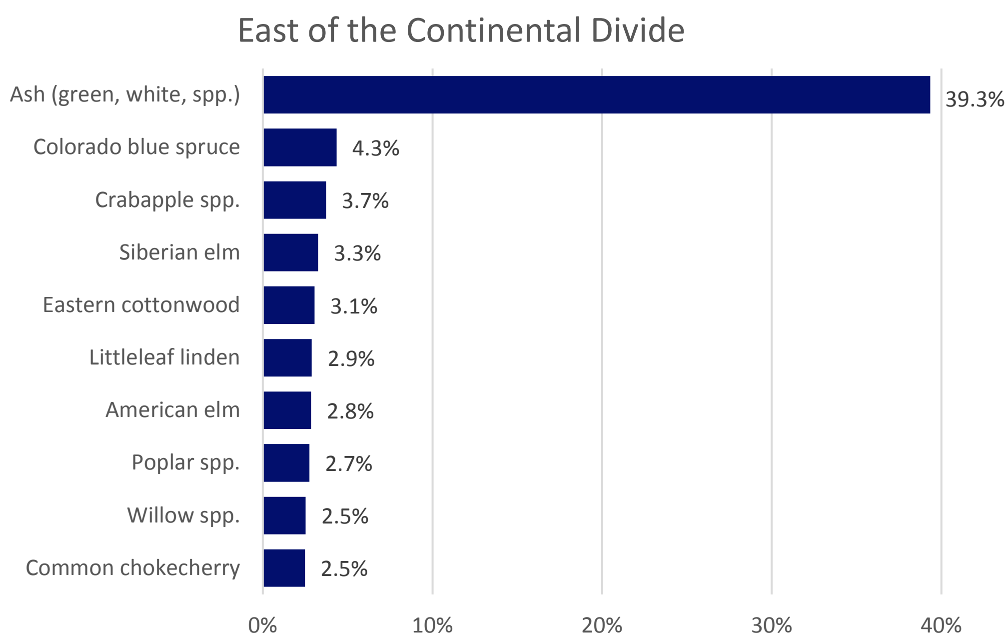


Figure 11: Top 10 Species East of Continental Divide

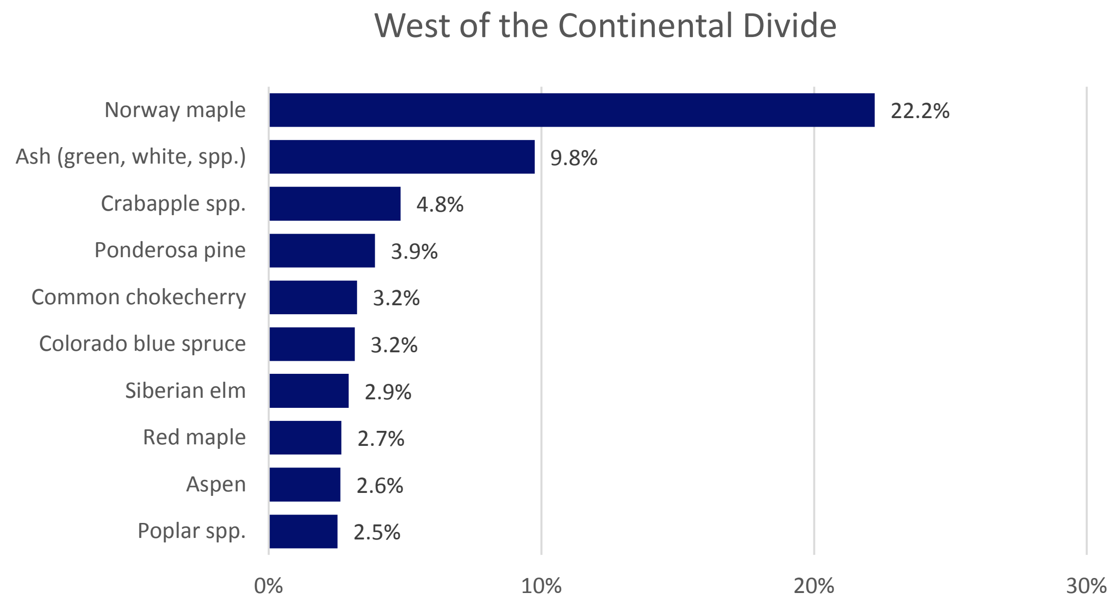


Figure 12: Top 10 Species West of the Continental Divide

Stocking Level

Community forests inventoried in Montana currently include at least 17,512 available planting sites and 1,471 stumps. (Planting sites were not counted in all communities). Considering the street tree inventories identified these planting sites in addition to 138,420 existing trees, the current overall stocking level of community forests is 87.9% (138,420/157,403). In addition, the inventories identified 363 trees that are recommended for immediate removal for public safety, 827 additional trees that are recommended for immediate removal, and 3,811 recommended for removal as routine maintenance over the next few years. If these removal locations are suitable for planting, an additional 5001 planting sites are available.

Relative Age Distribution

The distribution of individual tree ages within a tree population influences present and future costs as well as the flow of benefits. An ideally-aged population allows managers to allocate annual maintenance costs uniformly over many years and assures continuity in overall tree canopy coverage and associated benefits. The DBH range of the overall population and individual species is a good, general indicator of age. Trees with smaller diameters tend to be younger, although some trees with slow growth rates or trees growing in poor conditions may be older than the size of tree suggests. As a general practice, a desirable distribution has a high proportion of young trees to offset establishment and age-related mortality as the percentage of older trees declines over time (Richards 1983). This ideal distribution, albeit uneven, suggests that a large fraction of trees (~40%) should be young with diameters (DBH) less than eight inches, while only 10% should be in the large diameter classes (>24 inches DBH). DBH distributions vary by community, with some communities having a higher number of newly planted trees (under 8”) and some having a large maturing population (trees over 24”), but at the state level, the distribution of inventoried trees fits within the accepted practice.

Figure 13: Mature Cottonwoods in Hamilton

The overall age distribution of inventoried urban forests is nearly ideal, with 47% of trees 8 inches or less in diameter (DBH) and 11% of trees larger than 24 inches in diameter (Figure 14). With ongoing proactive management in communities with this exemplar distribution, the resource will continue to produce stable benefits, supporting the quality of life of the community and the environment. In communities with mature to older populations, new plantings could compensate for the approaching benefit decline.

Of the ten most common trees in Montana's community forests, the youngest populations are chokecherry (*Prunus virginiana*), little-leaf linden (*Tilia cordata*), and crabapple species (*Malus spp*.) (Figure 15). Over 70% of these species are 6 inches or less in diameter. This suggests that recent tree plantings have increased the prevalence of these species. The poplar species (*Populus spp*.) group contains more trees greater than 24 inches in diameter than any other species (41.3%). Siberian elm (*Ulmus pumila*) ranks second with 29.3% greater than 24 inches. These high percentages are likely due to the high number of these species planted when towns were first established and rapid growth rates. Norway maple (*Acer platanoides*), ash species (*Fraxinus spp*.), and Colorado blue spruce (*Picea pungens*) are all well-established populations throughout the state. These species provide significant representation of the middle-class sizes, between 8 inches and 24 inches diameter.

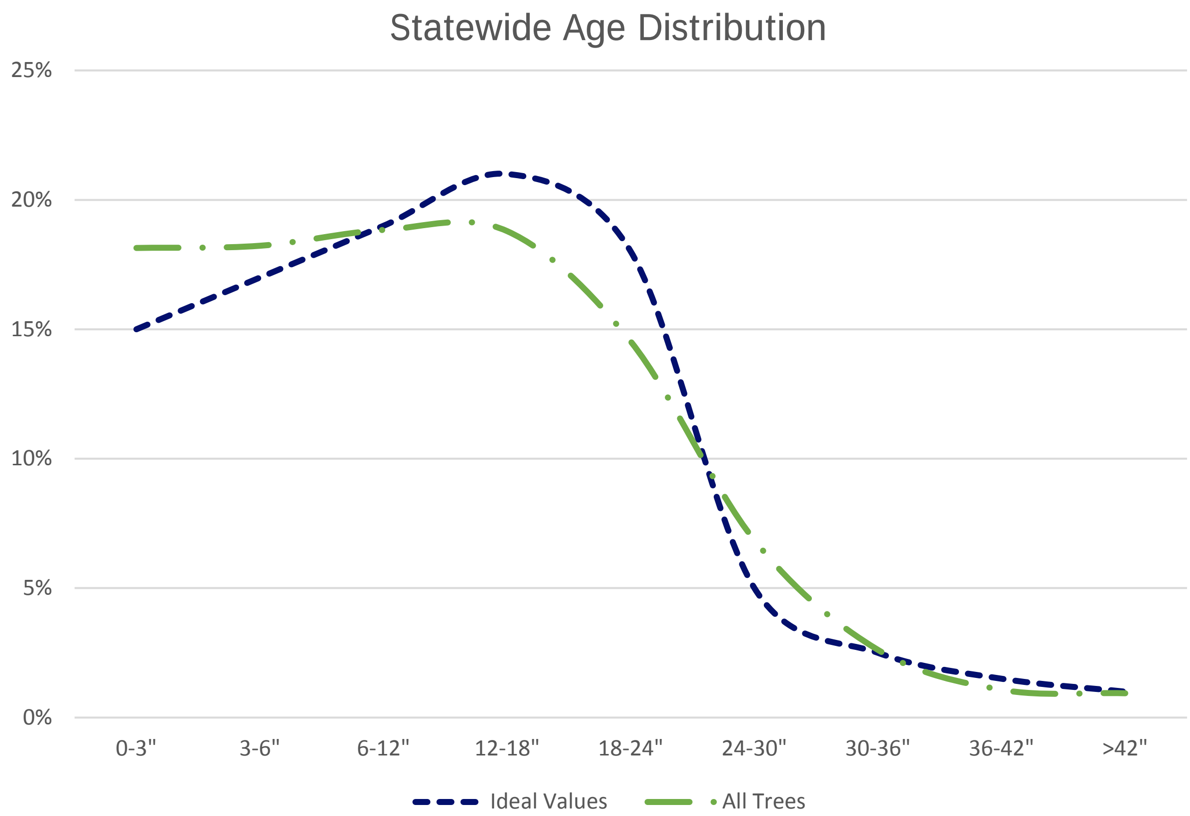
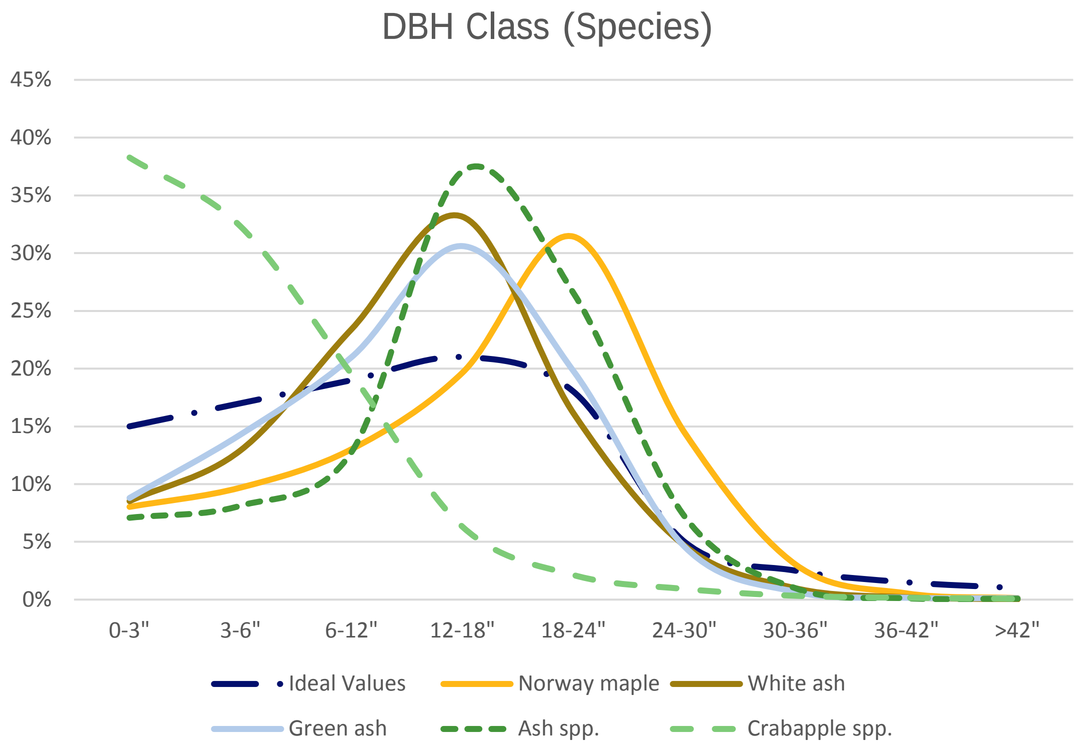


Figure 14: Statewide Age Distribution



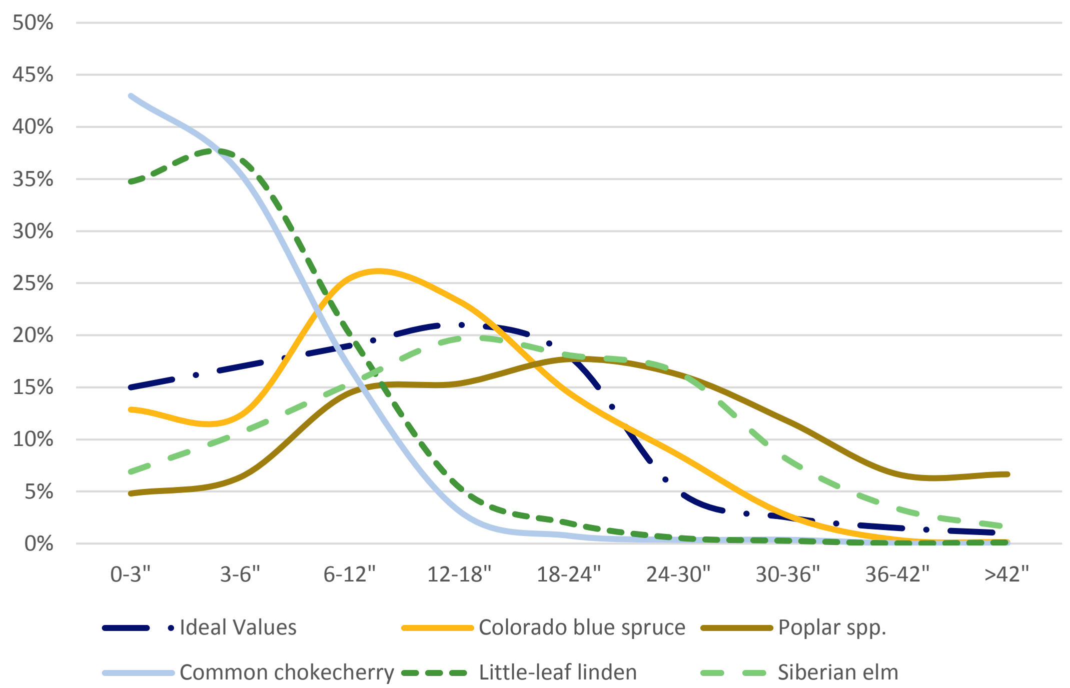


Figure 15: Age Distribution of the Top 10 Tree Species

Urban Forest Condition

Tree condition is an indication of how well trees are managed and how they are performing in given site-specific environments (e.g., street, median, parking lot, etc.). Condition ratings can help urban forest managers anticipate maintenance and funding needs and are an important factor for the calculation of urban forest benefits. A 'good' condition rating assumes that a tree has no major structural problems, no significant mechanical damage, and may have only minor aesthetic, insect, disease, or structural problems, and is in good health. Condition descriptions are defined in Appendix A.

Fifty-five percent of the trees in Montana's community forests are in overall good condition.

Thirty-one percent are in fair condition and fourteen percent are in poor condition or dead (Figure 16).

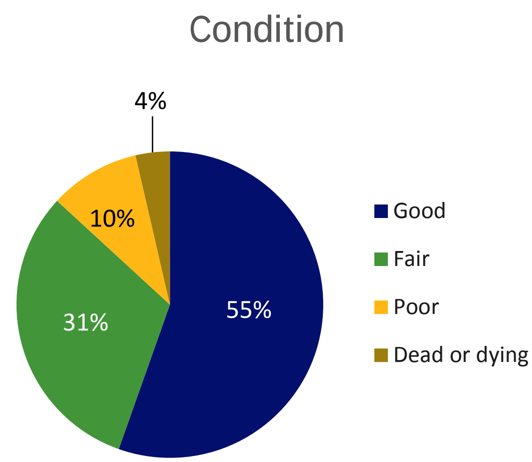


Figure 16: Condition Summary

The relative performance index (RPI) further analyzes the condition and suitability of specific tree species by comparing the condition rating of an individual tree species to that of every other tree species within the population. The RPI provides an urban forest manager with a threshold to assess species performance. The index compares the condition ratings of each tree species with the condition ratings of every other tree species within the population. An RPI of 1.00 or better indicates that the species is performing as well or better than average. An RPI value below 1.00 indicates that the species is not performing as well in comparison to the rest of the population.

Among the most common trees in the inventories (all species that represent more than 1%), 16 have an RPI of 1.00 or greater (Table 4). Of these, spruce (*Picea spp*., RPI=1.14), Austrian pine (*Pinus nigra*, RPI=1.12), and Colorado blue spruce (*Picea pungens*, RPI=1.11) have the highest RPI, while Siberian elm (*Ulmus pumila*, RPI=0.87), Norway maple (*Acer platanoides*, RPI=0.86), and boxelder (*Acer negundo*, RPI=0.85) have the lowest.

The RPI can be a useful tool for urban forest managers. For example, if a community has been planting two or more new species, the RPI can compare their relative performance. If the RPI indicates that one is performing relatively poorly, managers may decide to reduce or even stop planting that species to reduce expenditures on planting stock and replacement costs. The RPI also enables managers to look at the performance of long-standing species. Established species with an RPI of 1.00 or greater should be retained, and included in future plantings. It is important to keep in mind that, because RPI is based on condition at the time of the inventory, it may not reflect cosmetic, seasonal or nuisance issues that are not threatening the health or structure of the trees.

An RPI value less than 1.00 may be indicative of a species that is not well adapted to local conditions. Poorly adapted species are more likely to present safety and maintenance issues. Species with an RPI less than 1.00 should receive careful consideration before being chosen for future planting. However, prior to selecting or deselecting trees based on RPI alone, managers should consider the species age distribution and other factors. A species that has an RPI of less than 1.00, but has a significant number of trees in larger DBH classes, may simply be exhibiting signs of population senescence.

Table 4: Relative Performance Index for Most Prevalent Species (representing >1%)

Species	Dead or Dying	Poor	Fair	Good	RPI	# of Trees	% of Pop
Green ash	0.03	0.10	0.37	0.50	**0.99**	28070	20.28%
Norway maple	0.08	0.19	0.46	0.27	**0.86**	13374	9.66%
Ash spp.	0.03	0.10	0.44	0.43	**0.96**	6126	4.43%
Crabapple spp.	0.02	0.06	0.24	0.67	**1.05**	5748	4.15%
Colorado blue spruce	0.01	0.04	0.14	0.81	**1.11**	5380	3.89%
White ash	0.01	0.09	0.38	0.52	**1.00**	4480	3.24%
Siberian elm	0.08	0.19	0.43	0.29	**0.87**	4335	3.13%
Common chokecherry	0.02	0.05	0.19	0.74	**1.08**	3834	2.77%
Little-leaf linden	0.02	0.07	0.25	0.67	**1.05**	3683	2.66%
Poplar spp.	0.02	0.10	0.39	0.49	**0.99**	3682	2.66%
Honey locust	0.02	0.06	0.19	0.73	**1.08**	3130	2.26%
Ponderosa pine	0.01	0.03	0.13	0.83	**1.12**	3010	2.17%
Eastern cottonwood	0.03	0.05	0.24	0.68	**1.05**	2891	2.09%
Quaking aspen	0.06	0.11	0.25	0.59	**0.99**	2778	2.01%
American elm	0.05	0.06	0.32	0.57	**1.01**	2734	1.98%
Willow spp.	0.02	0.05	0.12	0.81	**1.10**	2478	1.79%
American linden	0.03	0.09	0.31	0.56	**1.01**	2152	1.55%
Broadleaf Deciduous Small	0.06	0.03	0.68	0.23	**0.91**	2107	1.52%
Red maple	0.04	0.14	0.35	0.47	**0.96**	1905	1.38%
Spruce spp.	0.01	0.01	0.07	0.90	**1.14**	1883	1.36%
Silver maple	0.06	0.14	0.25	0.55	**0.97**	1848	1.34%
Austrian pine	0.00	0.03	0.12	0.85	**1.12**	1629	1.18%
Douglas-fir	0.01	0.03	0.19	0.76	**1.09**	1470	1.06%
Engelmann spruce	0.01	0.07	0.21	0.72	**1.07**	1453	1.05%
Boxelder	0.09	0.25	0.35	0.32	**0.85**	1397	1.01%
Juniper spp.	0.01	0.03	0.17	0.79	**1.11**	1316	0.95%
Other	0.04	0.09	0.27	0.60	**1.01**	25527	18.44%
Total	4%	10%	31%	55%	1.00	138,420	100%

The RPI value can also help to identify underused species that are performing well. Trees with an RPI value greater than 1.00 and an "established population" (a species common enough to represent at least 0.5% of the tree population) may indicate their suitability in the local environment and should receive consideration for additional planting (Table 5).

Of trees with a population between .5% and 1%, the tree with the highest RPI value is the bur oak (*Quercus macrocarpa*, RPI=1.10), which represents 0.57% of the tree population (793 bur oaks/138,420 total trees). The common hackberry, *Celtis occidentalis*, which is 0.81% of the tree population, has a high RPI of 1.07. Either tree would be a good consideration for additional planting.

When considering new species based on RPI, it is important to base the decision on established populations. The greater the number of trees of a particular species, the more relevant the RPI becomes. The following species appear to be performing well and should be considered for future tree plantings:

Table 5: Species that May Be Underused

Species	RPI	# of Trees	% of Pop
Bur oak	**1.10**	793	0.57
Rocky Mountain juniper	**1.09**	693	0.50
Maple spp.	**1.07**	858	0.62
Common hackberry	**1.07**	1121	0.81
White poplar	**1.02**	1120	0.81
Lilac spp.	**1.01**	764	0.55

Replacement Value

The replacement value accounts for the historical investment in trees over their lifetime and is a way of describing the value of a tree population (and/or the average value per tree) at a given time. The replacement value reflects current population numbers, stature, placement, and condition. Distinguishing the replacement value from the value of annual economic, environmental, social and public health benefits produced by this urban forest resource is very important. There are several methods available for obtaining a fair and reasonable perception of a tree's value (CTLA, 1992; Watson, 2002). The cost approach, trunk formula method used in this analysis assumes the value of a tree is equal to the cost of replacing the tree in its current state (Cullen, 2002).

The combined value of Montana's community forests is more than $185.5 million (Table 6). The average replacement value per tree is $1,340. Ash (*Fraxinus pennsylvanica, americana* and spp. [green, white and spp.]) and Norway maple (*Acer platanoides*) are the most valuable populations representing $71.8 million, 38% of the overall replacement value and 38% of the overall urban forest resource.

Table 7 shows the replacement value of trees per community. Missoula's trees have the highest overall value ($22.9 million) (Figure 17), and Lodge Grass has the highest value per tree ($3,382 per tree). While it can be expected for Missoula to have a high overall value, as it is the community with the most inventoried trees, Lodge Grass has the fewest trees. The high per-tree value can be explained by taking into consideration the trees' stature, location, and condition.

Montana's community trees represent a vital component of community infrastructure and a public asset that with proper care and maintenance will continue to increase in value over time.

Table 6: Replacement Value Summary

Species	Total $	% of Total	% of Pop
Green ash	**$36,195,765**	19.51	20.28
Norway maple	**$20,666,899**	11.14	9.66
Ash spp.	**$9,490,781**	5.12	4.43
Crabapple spp.	**$2,491,757**	1.34	4.15
Colorado blue spruce	**$9,063,186**	4.88	3.89
White ash	**$5,494,052**	2.96	3.24
Siberian elm	**$8,208,864**	4.42	3.13
Common chokecherry	**$1,199,294**	0.65	2.77
Little-leaf linden	**$1,483,867**	0.80	2.66
Poplar spp.	**$12,058,120**	6.50	2.66
Other trees	**$79,181,338**	42.68	43.14
All trees	**$185,533,923**	**100%**	**100%**

Figure 17: As Trees Mature their Replacement Value Increases (Silver Park, Missoula)

Table 7: Per-Community Replacement Value Summary

Community	Value	Number of Trees	Per-Tree Value
Alberton	$170,331	101	$1,686
Anaconda	$3,817,421	2,346	$1,627
Big Timber	$2,061,365	1,069	$1,928
Billings Park	$14,267,515	8,335	$1,712
Bozeman	$11,677,243	10,559	$1,106
Broadus	$552,491	731	$756
Browning	$265,901	344	$773
Butte	$4,920,519	4,404	$1,117
Cascade	$667,550	418	$1,597
Choteau	$2,963,305	1,354	$2,189
Colstrip	$907,002	855	$1,061
Columbia Falls	$4,350,594	3,339	$1,303

Community	Value	Number of Trees	Per-Tree Value
Columbus	$2,792,760	1,192	$2,343
Conrad	$2,443,445	1,203	$2,031
Culbertson	$582,470	339	$1,718
Cut Bank	$708,313	577	$1,228
Dillon	$1,011,743	781	$1,295
Drummond	$295,478	276	$1,071
Ennis	$265,317	216	$1,228
Eureka	$438,305	364	$1,204
Forsyth	$2,006,139	716	$2,802
Fort Benton	$2,221,082	895	$2,482
Fort Peck	$993,486	584	$1,701
Glasgow	$1,622,354	1,603	$1,012
Glendive	$3,994,848	1,987	$2,010
Great Falls Malmstrom AFB	$5,055,819	8,610	$587
Hamilton	$4,099,701	1,639	$2,501
Hardin	$1,276,249	1,000	$1,276
Harlowton	$1,807,390	1,080	$1,674
Havre	$6,362,590	3,554	$1,790
Helena	$8,593,055	9,385	$916
Judith Gap	$38,378	148	$259
Kalispell	$10,718,579	9,077	$1,181
Laurel	$4,681,946	3,361	$1,393
Lewiston	$4,425,780	2,665	$1,661
Libby	$1,680,955	1,751	$960
Livingston	$7,962,169	3,888	$2,048
Lodge Grass	$290,872	86	$3,382
Manhattan	$1,194,913	774	$1,544
Miles City	$10,202,381	4,238	$2,407
Missoula	$22,885,476	22,537	$1,015
Plentywood	$1,048,391	606	$1,730
Polson	$2,478,907	1,584	$1,565
Red Lodge	$2,786,956	2,205	$1,264
Ronan	$1,456,196	867	$1,680
Roundup	$2,769,185	1,548	$1,789
Saco	$123,019	116	$1,061
Shelby	$1,405,592	1,364	$1,030
Sheridan	$184,747	141	$1,310
Sidney	$3,322,735	2,125	$1,564
Stanford	$250,510	297	$843
Stevensville	$1,601,367	614	$2,608
Superior	$845,460	347	$2,436
Thompson Falls	$1,306,850	623	$2,098
Townsend	$1,167,366	997	$1,171
Valier	$516,258	564	$915
West Yellowstone	$444,951	637	$699
Whitefish	$3,532,751	3,474	$1,017
Whitehall	$531,255	422	$1,259
White Sulfur Springs	$1,015,056	492	$2,063
Wolf Point	$1,476,415	1,016	$1,453
Total:	**$185,537,198**	**138,420**	**$1,340**

Benefits from Montana's Urban Forest

Trees conserve and reduce energy use, reduce global carbon dioxide (CO_2) levels, improve air quality, and mitigate stormwater runoff. They provide a wealth of well-documented psychological, social, and economic benefits related primarily to aesthetics. The question remains, however, if the collective benefits are worth the cost of the investment? To answer this question, the benefits are quantified in financial terms.

The analysis model quantifies benefits based on regional reference cities and local community attributes, such as median home values and local energy prices. This analysis provides a snapshot of the annual benefits (along with the value of those benefits) produced by Montana's community forests. While the annual benefits can be substantial, it is important to recognize that the greatest benefits occur over time, from mature urban forests where trees are well-managed, healthy, and long-lived (Figure 18).

This analysis used current inventory data for Montana's community trees and MyTreekeeper® and Treekeeper® version 7.7 software to quantify and assess the beneficial functions of the resource. The software determines a dollar value for the annual benefits these trees provide. The benefits calculated are estimations based on the best available and current scientific research with an accepted degree of uncertainty. The data returned can provide a platform from which informed management decisions can be made (Maco and McPherson, 2003). A discussion on the methods used to calculate and assign a monetary value to these benefits is included in Appendix A.

Figure 18: Mature Trees in Peterson Park Provide Benefits to the Sidney Community

Energy Savings

Trees modify climate and conserve energy in three principal ways:

- Shading reduces the amount of radiant energy absorbed and stored by hardscape surfaces, thereby reducing the heat island effect of urban areas.
- Transpiration converts moisture to water vapor, cooling the air and absorbing solar energy that would otherwise increase temperature.
- Reduction of wind speed, outside to inside air movement, and conductive heat loss through glass windows (Simpson 1998).

The heat island effect describes the increase in urban temperatures in relation to surrounding suburban and rural areas. Heat islands are associated with an increase in hardscape and impervious surfaces. Trees and other vegetation within an urbanized environment help reduce the heat island effect by lowering air temperatures 5°F (3°C) (Chandler 1965). On a broader scale, temperature differences of more than 9°F (5°C) have been observed between city centers without adequate canopy coverage and more vegetated suburban areas (Akbari 1992). The relative importance of these effects depends on the size and configuration of trees and other landscape elements (McPherson 1993). Tree spacing, crown spread, and vertical distribution of leaf area each influence the transport of warm air and pollutants along streets and out of urban canyons. Trees reduce conductive heat loss from buildings by reducing air movement into buildings and against conductive surfaces (e.g., glass, metal siding). Trees can reduce wind speed and the resulting air infiltration by up to 50%, translating into potential annual heating savings of 25% (Heisler 1986).

These savings are important in Montana because of frequent extreme temperature fluctuations, high winds, and the overall variable climate. Trees can serve in a functional capacity to provide the best benefits for any particular community's conditions. For example, in communities with high wind speeds such as Shelby or Livingston, using trees as shelterbelts will provide protection along with environmental benefits.

Electricity and Natural Gas Reduction

Electricity and natural gas saved annually in Montana from both the shading and climate effects of community trees is equal to 12,456 MWh and 1,160,647.60 therms, for a total retail savings of approximately $1,844,435 ($13.32 average per tree) (Table 8). The electricity savings is equivalent to running 2,491 central air conditioning units in homes for 1,000 hours each, and the natural gas savings is equivalent to heating 8,000 houses (2,500 square feet) for a month. Of the top ten most prevalent species, those that contribute most to energy benefits on a per-tree basis include Siberian elm (*Ulmus pumila*), with an average value of $27.24 annually, and poplar (*Populus spp.*) with an average value of $25.24 per tree (Figure 19). The elevated level of benefits provided by these two species are likely due to their medium-to-large stature and the maturity of the populations.

Small-canopy trees are less able to provide electricity and natural gas reduction benefits. On a per-tree basis, chokecherry (*Prunus virginiana*) provides $2.34 in average annual benefits and it is providing just 0.5% of the energy benefits (Table 8). This is a small-statured tree with 79% of its population less than 6 inches DBH. Apple/crabapple species (*Malus spp.*) provides $3.06 in average benefits while providing 1% of the energy benefits. This is another small-stature tree with 90% of its population less than 12 inches DBH. These energy benefits will increase over time as this younger population matures and grows in size.

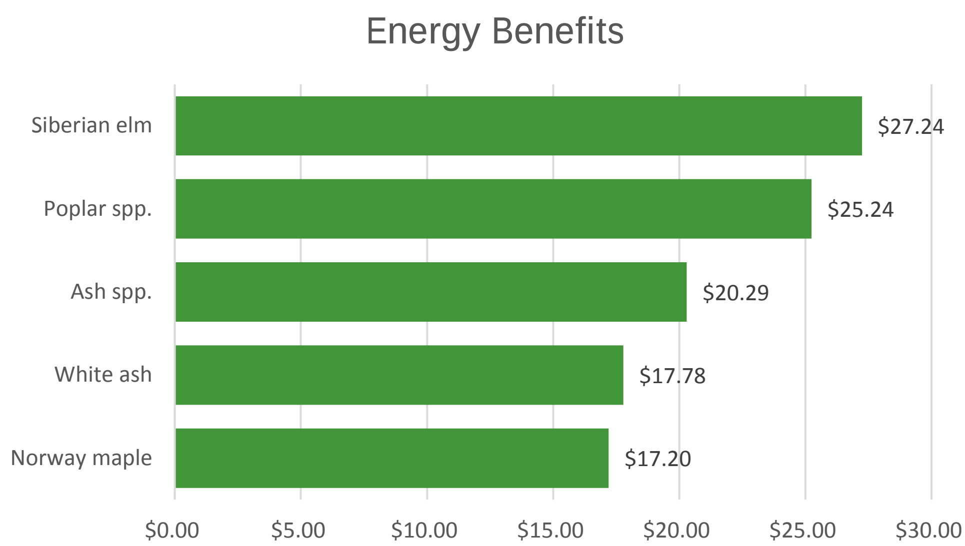


Figure 19: Top Five Highest Per-Tree Annual Electricity and Natural Gas Benefits

Table 8: Annual Electric and Natural Gas Benefits

Species	Total Electricity (KWh)	Total Natural Gas (Therms)	Total ($)	% of Pop	% of Total $	Avg. $/tree
Green ash	3,141,479	293,375	**$465,772**	20.28	25.25	**$16.59**
Norway maple	1,571,355	143,466	**$230,004**	9.66	12.47	**$17.20**
Ash spp.	848,825	77,543	**$124,286**	4.43	6.74	**$20.29**
Crabapple spp.	108,897	11,773	**$17,599**	4.15	0.95	**$3.06**
Colorado blue spruce	351,992	41,068	**$59,619**	3.89	3.23	**$11.08**
White ash	525,022	51,037	**$79,661**	3.24	4.32	**$17.78**
Siberian elm	816,339	72,986	**$118,089**	3.13	6.40	**$27.24**
Common chokecherry	53,680	6,112	**$8,956**	2.77	0.49	**$2.34**
Little-leaf linden	100,442	11,242	**$16,580**	2.66	0.90	**$4.50**
Poplar spp.	673,391	55,256	**$92,922**	2.66	5.04	**$25.24**
Other Trees	4,264,428	396,790	**$630,947**	43.14	34.21	**$10.57**
All Trees	**12,455,850**	**1,160,648**	**$1,844,435**	**100%**	**100%**	**$13.32**

Atmospheric Carbon Dioxide Reduction

As environmental awareness continues to increase, local governments will pay particular attention to climate change and the effects of greenhouse gas (GHG) emissions. As energy from the sun (sunlight) strikes the Earth's surface it is reflected back into space as infrared radiation (heat). Greenhouse gases absorb some of this infrared radiation and trap heat in the atmosphere, modifying the temperature of the Earth's surface. Many chemical compounds in the Earth's atmosphere act as GHGs, including methane (CH_4), nitrous oxide (N_2O), carbon dioxide (CO_2), water vapor, and human-made gases and aerosols. As GHGs increase, the amount of energy radiated back into space decreases, trapping more heat in the atmosphere. Increases in the average temperature of the earth are resulting in changes in weather, sea levels, and land-use patterns. In the last 150 years, since large-scale industrialization began, the levels of some GHGs, including CO_2, have increased by 25 percent (U.S. Energy Information Administration).

The Center for Urban Forest Research (CUFR) recently led the development of Urban Forest Project Reporting Protocol. The protocol, which incorporates methods of the Kyoto Protocol and Voluntary Carbon Standard (VCS), establishes methods for calculating reductions, provides guidance for accounting and reporting, and guides urban forest managers in developing tree planting and stewardship projects that could be registered for GHG reduction credits (offsets). The protocol can be applied to urban tree planting projects within municipalities, campuses, and utility service areas anywhere in the United States.

Urban trees reduce atmospheric CO_2 in two ways:

- Directly, through growth and the sequestration of CO_2 in wood, foliar biomass, and soil.
- Indirectly, by lowering the demand for heating and air conditioning, thereby reducing the emissions associated with electric power generation and natural gas consumption.

Conversely, vehicles and other combustion engines used to plant and care for trees release CO_2 during operation and CO_2 is released back into the atmosphere during decomposition, after trees die. Each of these factors must be considered when calculating the net CO_2 benefits of trees.

Carbon Dioxide Benefits

Annually, community trees in Montana sequester 4,768 tons of CO_2 into woody and foliar biomass and avoid[3] 5,874 tons of CO_2, valued at $147,635. This is equivalent to the amount of CO_2 produced by burning 1.1 million gallons of gasoline. Of the top ten most prevalent species, Siberian elm, poplar spp. and ash (green ash, white ash and ash spp. combined) currently provide the highest annual per tree benefits ($2.29/Siberian elm, $2.23/poplar spp, $2.16/combined ash) (Table 9, Figure 20). Ash trees provide the overall highest amount of annual carbon benefits, valued at $62,327, 64% of the total benefit.

[3] Avoided Carbon: Avoided carbon is a result of reducing energy consumption. The avoided value represents carbon that would have been created from the production of additional energy.

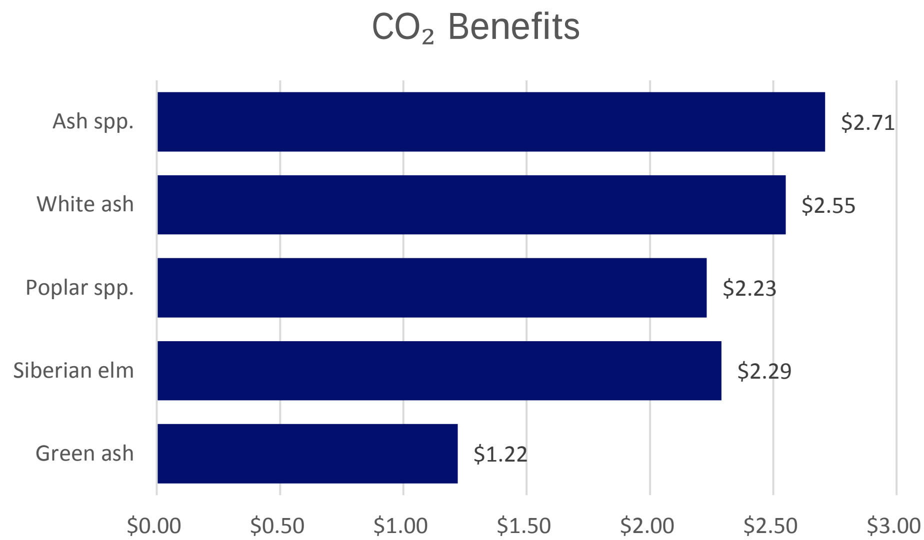


Figure 20: Top Five Highest Per-Tree Annual Carbon Benefits

Table 9: Summary of Annual Carbon Benefits

Species	Sequestered (lb.)	Avoided (lb.)	Total ($)	% of Pop	% of Total $	Avg. $/tree
Green ash	2,306,288	2,551,826	**$34,282**	20.28	23.22	**$1.22**
Norway maple	479,484	608,411	**$7,417**	9.66	5.02	**$0.55**
Ash spp.	1,117,931	1,244,151	**$16,615**	4.43	11.25	**$2.71**
Crabapple spp.	235,050	208,337	**$3,060**	4.15	2.07	**$0.53**
Colorado blue spruce	277,867	360,061	**$4,364**	3.89	2.96	**$0.81**
White ash	779,760	834,418	**$11,430**	3.24	7.74	**$2.55**
Siberian elm	608,105	802,128	**$9,932**	3.13	6.73	**$2.29**
Common chokecherry	48,403	37,520	**$597**	2.77	0.40	**$0**
Little-leaf linden	40,555	66,942	**$759**	2.66	0.51	**$0.21**
Poplar spp.	491,375	734,835	**$8,210**	2.66	5.56	**$2.23**
Other Trees	3,151,724	4,299,635	**$50,970**	43.14	34.52	**$0.85**
All Trees	**9,536,542**	**11,748,263**	**$147,635**	**100%**	**100%**	**$1.07**

Air Quality Improvement

Urban trees improve air quality in five fundamental ways:

- Absorption of gaseous pollutants such as ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) through leaf surfaces
- Interception of particulate matter (PM_{10}), such as dust, ash, dirt, pollen, and smoke
- Reduction of emissions from power generation by reducing energy consumption
- Increase of oxygen levels through photosynthesis
- Transpiration (the process of water movement and evaporation in plants) and shade provision, resulting in lower local air temperatures, thereby reducing ozone (O_3) levels

PM_{10} is particulate matter in the air that measures less than 10 micrometers, smaller than the width of a single human hair. These small particles or liquid droplets include smoke, soot, dust, and secondary reactions from gaseous pollutants. PM_{10} pollution is detrimental to health and can cause respiratory problems for local residents.

Ozone (O_3) is another air pollutant that is harmful to human health. Ozone forms when nitrogen oxides from fuel combustion and volatile organic gases from evaporated petroleum products react in the presence of sunshine.

In the absence of cooling effects provided by trees, higher temperatures contribute to ozone (O_3) formation. Additionally, short-term increases in ozone concentrations are statistically associated with increased tree mortality (Bell et al. 2004).

While trees do a great deal to absorb air pollutants (especially ozone and particulate matter), they also negatively contribute to air pollution. Trees emit various biogenic volatile organic compounds (BVOCs), such as isoprenes and monoterpenes, which contribute to ozone formation. The analysis for this inventory accounts for these BVOC emissions in the air quality net benefit calculation.

In Montana, air quality issues include drought-related dust in the eastern ranching and farming communities, and smoke inversions in western mountain valley communities. Smoke from wildfires affects not only the wildland urban interface, but also entire communities in a large radius surrounding the incident. Large wildfires in the western United States can pump as much carbon dioxide into the atmosphere in just a few weeks as cars do in those areas in an entire year. A community with a healthy urban tree population can help trap, settle, and hold dust and particulate pollutants from smoke and combat some of the CO_2 emitted from the fires (Thompson 2007). Table 10 includes management strategies for improving air quality.

Table 10: Urban Forest Management Strategies to Improve Air Quality

Strategy	Result
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduce 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	Minimize pollutants emissions from maintenance activities
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	Maximize tree air quality benefits
Avoid pollutant-sensitive species	Reduce tree maintenance and replacement
Utilize evergreen trees for particulate matter	Year-round removal of particles

Air Quality Benefits

Each year, 47,513 pounds of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), small particulate matter (PM_{10}), and ozone (O_3) are intercepted, absorbed or avoided by community trees, for a value of $123,273. The highest value per tree is the poplar (*Populus spp*.) at $2.42 per tree (Figure 21). Ash trees (green, white and spp.) are the greatest contributors to pollutant interception and absorption, accounting for 37% of these benefits (Table 11).

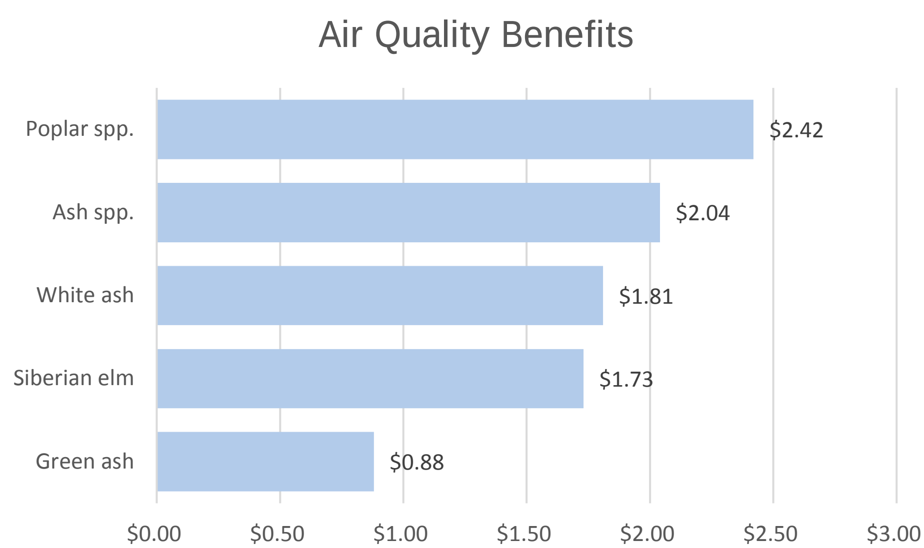


Figure 21: Top Five Highest Per-Tree Air Quality Benefits

Table 11: Summary of Annual Air Quality Benefits

Species	Pollutants (lb.)	Total benefit ($)	% of Pop	% of Total $	Avg. $/tree
Green ash	10,072	**$24,639**	20.28	19.99	**$0.88**
Norway maple	2,945	**$6,952**	9.66	5.64	**$0.52**
Ash spp.	4,756	**$12,517**	4.43	10.15	**$2.04**
Crabapple spp.	867	**$2,533**	4.15	2.05	**$0.44**
Colorado blue spruce	1,399	**$3,410**	3.89	2.77	**$0.63**
White ash	3,138	**$8,130**	3.24	6.60	**$1.81**
Siberian elm	3,065	**$7,521**	3.13	6.10	**$1.73**
Common chokecherry	158	**$396**	2.77	0.32	**$0.10**
Little-leaf linden	306	**$759**	2.66	0.62	**$0.21**
Poplar spp.	3,112	**$8,908**	2.66	7.23	**$2.42**
Other Trees	17,695	**$47,508**	43.14	38.54	**$0.80**
All Trees	**47,513**	**$123,273**	**100%**	**100%**	**$0.89**

Stormwater Runoff Reductions

Rainfall interception by trees reduces the amount of stormwater that enters collection and treatment facilities during large storm events. Trees intercept rainfall in their canopy controlling runoff at the source. Healthy urban trees reduce the amount of runoff and pollutant loading in receiving waters in three primary ways:

- Leaf and branch surfaces intercept and store rainfall, reducing runoff volumes and delaying the onset of peak flows.
- Root growth and decomposition create pore space which increases the capacity and rate of soil infiltration by rainfall and reduces overland flow.
- Tree canopies reduce soil erosion and surface flows by diminishing the impact of raindrops on bare soil.

Community trees in Montana intercept more than 122.4 million gallons of stormwater annually for an average of 884 gallons per tree. The statewide stormwater runoff reduction diverts enough water to fill 185 Olympic swimming pools annually. The total annual value of this benefit to the state is $1,321,925, an average of $9.55 per tree.

Among the top ten genera and species, Siberian elm (*Ulmus pumila*) currently provides the greatest per-tree benefit of $32.18, followed by poplar (*Populus spp.*) at $18.72 per tree (Figure 22, Table 12).

As trees grow, their benefits increase due to stature and canopy; but some species will ultimately realize more substantial benefits than others. The tree species group contributing the least benefits are small-canopy broadleaf deciduous trees. Their benefits will not increase much over time. Chokecherry (*Prunus virginiana*, $0.57/tree) is one example of a small-canopy tree with lower benefits. However, medium- or large-stature trees such as little-leaf linden (*Tilia cordata*, $2.37/tree) which have a high percentage of immature trees in the current population, should see increased benefits as these younger individuals mature.

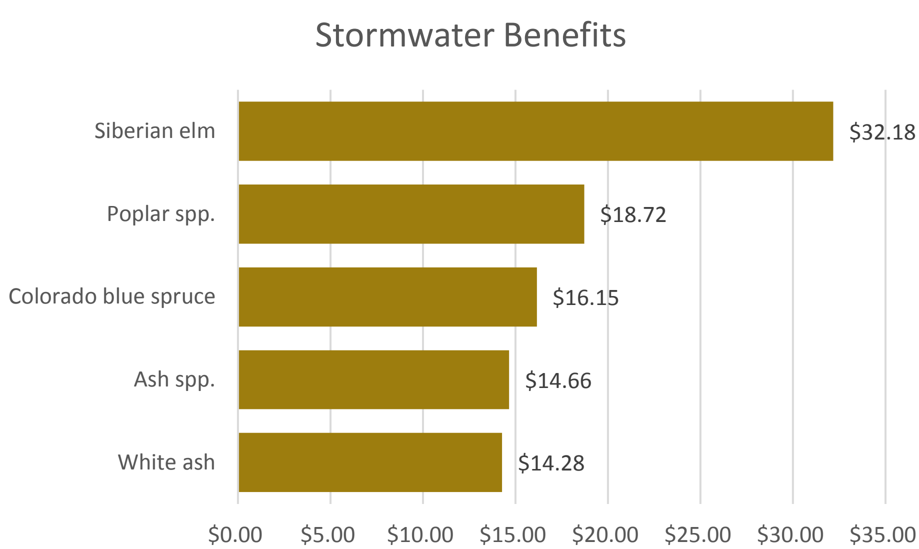


Figure 22. Top Five Highest Annual Stormwater Benefits

Table 12. Summary of Annual Stormwater Runoff Reduction Benefits

Species	Total Rainfall Interception (Gal)	Total ($)	% of Pop	% of Total $	Avg. $/tree
Green ash	22,619,185	**$244,287**	20.28	18.48	**$8.70**
Norway maple	10,442,075	**$112,774**	9.66	8.53	**$8.43**
Ash spp.	8,315,863	**$89,811**	4.43	6.79	**$14.66**
Crabapple spp.	720,202	**$7,778**	4.15	0.59	**$1.35**
Colorado blue spruce	8,047,093	**$86,909**	3.89	6.57	**$16.15**
White ash	5,924,867	**$63,989**	3.24	4.84	**$14.28**
Siberian elm	12,916,084	**$139,494**	3.13	10.55	**$32.18**
Common chokecherry	203,957	**$2,203**	2.77	0.17	**$0.57**
Little-leaf linden	808,788	**$8,735**	2.66	0.66	**$2.37**
Poplar spp.	6,380,828	**$68,913**	2.66	5.21	**$18.72**
Other Trees	46,021,541	**$497,033**	43.14	37.60	**$8.32**
All Trees	**122,400,482**	**$1,321,925**	**100%**	**100%**	**$9.55**

Aesthetic, Property Value, and Socioeconomic Benefits

Trees provide beauty in the urban landscape, privacy for homeowners, improved human health, a sense of comfort and place, and habitat for urban wildlife (Figure 23). Research shows that trees promote better business by stimulating more frequent and extended shopping and a willingness to pay more for goods and parking (Wolf 1999). Some of these benefits capture a percentage of the value of the property on which a tree stands. To determine the value of these less tangible benefits, MyTreekeeper® uses research that compares differences in sales prices of homes to estimate the contribution associated with trees. Differences in housing prices in relation to the presence or absence of a street tree help define the aesthetic value of street trees in the urban environment.

The calculation of annual aesthetic, property value and socioeconomic benefits corresponds with a tree's annual increase in leaf area. This equation uses the average sales prices of homes in the region, the value a large tree adds to a home, and the leaf surface area. When a tree is actively growing, leaf area may increase dramatically. Once a tree is mature, there may be little or no net increase in leaf area from one year to the next; thus, there is little or no incremental annual aesthetic benefit for that year even though the cumulative benefit over the course of the entire life of the tree may be large. Since this report represents a one-year sample snapshot of the inventoried tree population, aesthetic benefits reflect the increase in leaf area for each species population over the course of a single year.

The total annual benefit from community trees associated with property value increases and other less tangible benefits is almost $13.7 million, an average of $99 per tree (Table 13, Figure 24). This property value benefit would buy nearly 71 homes in Montana at median price. Overall, among the top ten most prevalent species, Siberian elm (*Ulmus pumila*, $197.93) and ash (*Fraxinus spp*., $145.95) provide the greatest per-tree property value annually, likely due to large leaf surface area.

Figure 23. Ash Trees in Columbus Provide Aesthetic Values to the Community

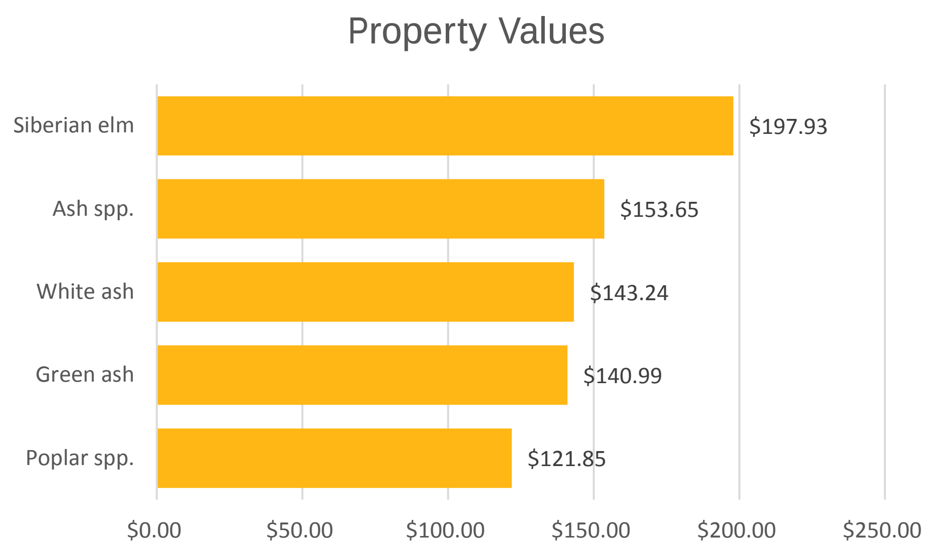


Figure 24. Top Five Species with the Highest Property Value Benefits

Table 13. Summary of Annual Aesthetic, Property Value, and Socioeconomic Benefits

Species	Total ($)	% of Pop	% of Total $	Avg. $/tree
Green ash	**$3,957,573**	20.28	28.79	**$140.99**
Norway maple	**$1,255,208**	9.66	9.13	**$93.85**
Ash spp.	**$941,266**	4.43	6.85	**$153.65**
Crabapple spp.	**$207,678**	4.15	1.51	**$36.13**
Colorado blue spruce	**$405,759**	3.89	2.95	**$75.42**
White ash	**$641,727**	3.24	4.67	**$143.24**
Siberian elm	**$858,044**	3.13	6.24	**$197.93**
Common chokecherry	**$127,776**	2.77	0.93	**$33.33**
Little-leaf linden	**$267,863**	2.66	1.95	**$72.73**
Poplar spp.	**$448,635**	2.66	3.26	**$121.85**
Other Trees	**$4,635,914**	43.14	33.72	**$77.64**
All Trees	**$13,747,444**	**100%**	**100%**	**$99.32**

Summary of Benefits

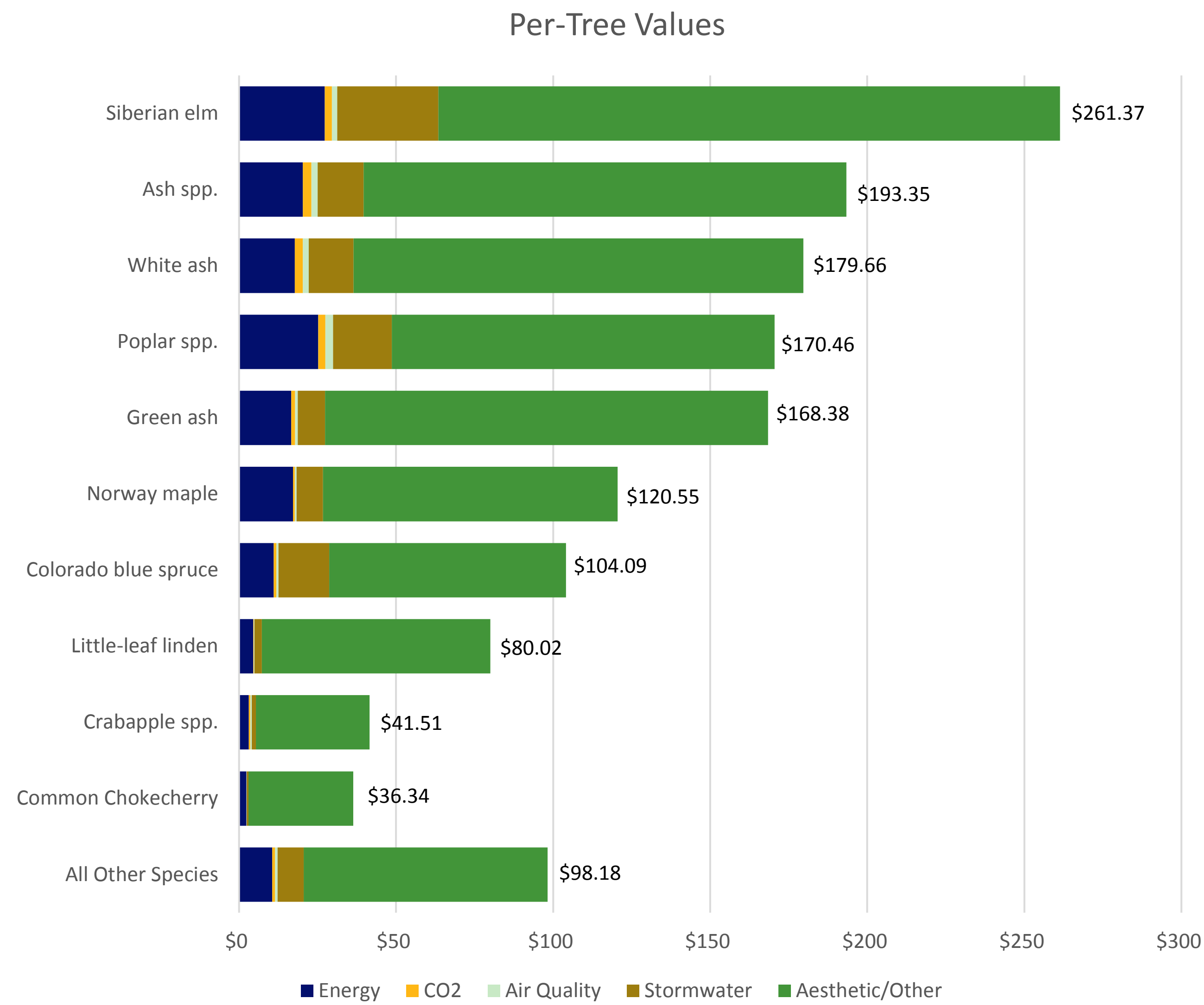


Figure 25. Summary of Annual Per-Tree Benefits for the Top Ten Species

Table 14. Summary of Annual Per-Tree Benefits for the Top Ten Species

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total
Green ash	$16.59	$1.22	$0.88	$8.70	$140.99	**$168.38**
Norway maple	$17.20	$0.55	$0.52	$8.43	$93.85	**$120.56**
Ash spp.	$20.29	$2.71	$2.04	$14.66	$153.65	**$193.36**
Crabapple spp.	$3.06	$0.53	$0.44	$1.35	$36.13	**$41.52**
Colorado blue spruce	$11.08	$0.81	$0.63	$16.15	$75.42	**$104.10**
White ash	$17.78	$2.55	$1.81	$14.28	$143.24	**$179.67**
Siberian elm	$27.24	$2.29	$1.73	$32.18	$197.93	**$261.38**
Common chokecherry	$2.34	$0	$0.10	$0.57	$33.33	**$36.50**
Little-leaf linden	$4.50	$0.21	$0.21	$2.37	$72.73	**$80.01**
Poplar spp.	$25.24	$2.23	$2.42	$18.72	$121.85	**$170.45**
Other Trees	$10.57	$0.85	$0.80	$8.32	$77.64	**$98.18**
All Trees	**$13.32**	**$1.07**	**$0.89**	**$9.55**	**$99.32**	**$124.15**

Figure 26: Siberian Elms Provide the Greatest Overall Per-Tree Benefit

Benefit-Investment Ratio (BIR)

Montana receives substantial benefits from community forests; however, the communities must also consider their investments in maintaining this resource. Applying a *benefit-investment ratio* (BIR) is a useful way to evaluate the public investment in a community tree resource. The benefit-investment ratio is used to summarize the overall value compared to the investments of a given resource. In this analysis, BIR is the ratio of the total value of benefits provided by all inventoried trees compared to the cost (investment) associated with their management.

A BIR was generated for all Tree City USA communities with inventory and budget data (40 communities) (Table 15). Tree City USA-reported expenditures may differ from standard municipal budgetary information as this program includes grant funding, volunteer hours, in-kind funds, local donations, adopt-a-tree programs, and other similar figures that typically are not considered in municipal budgets.

The total estimated community urban forest benefits provided by the combined inventories of the 40 Tree City USA communities is almost $14.5 million, a value of $119 per tree and $31 per capita. These benefits are realized on an annual basis. It is important to acknowledge that this is not a full accounting of the benefits provided by this resource, as some benefits are intangible and/or difficult to quantify, such as impacts on psychological health, crime, and violence. Empirical evidence of these benefits does exist (Wolf 2007, Kaplan 1989, Ulrich 1986), but limited knowledge about the physical processes at work and the complex nature of interactions makes quantification imprecise. Tree growth and mortality rates are highly variable. A true and full accounting of benefits and investments must assess variability among sites (e.g., tree species, growing conditions, maintenance practices) and variability in tree growth. Some trees may be worth far more than this analysis conveys**.**

Considering the total budget (investment) of Tree City USA communities ($3.3 million), the total annual net benefit (benefits minus investment) is $11.2 million. The average net benefit for an individual community tree is $92 and the per capita net benefit is $24. For every $1 dollar invested in the urban forest, Tree City USA communities in Montana are receiving $4.41 in benefits.

Table 15. Tree City USA Benefits Investment Ratio (BIR)

Community	Population	Expenditures	Per capita	Benefits	Qty. Trees	BIR
Anaconda	9,139	$36,829	$4.03	$303,074	2,346	**$8.23**
Billings	110,263	$267,323	$2.42	$1,008,729	8,335	**$3.77**
Bozeman	43,405	$533,073	$12.28	$1,205,748	10,559	**$2.26**
Broadus	488	$1,800	$3.69	$78,892	731	**$43.83**
Butte	33,922	$106,852	$3.15	$345,347	4,404	**$3.23**
Cascade	696	$3,438	$4.94	$50,196	418	**$14.60**
Choteau	1,696	$7,287	$4.30	$215,218	1,354	**$29.53**
Columbia Falls	5,093	$14,222	$2.79	$197,077	3,339	**$13.86**
Dillon	4,210	$25,390	$6.03	$125,563	781	**$4.95**
Drummond	336	$1,028	$3.06	$28,628	276	**$27.84**
Ennis	884	$2,965	$3.35	$23,559	216	**$7.95**
Eureka	1,074	$6,675	$6.22	$31,191	364	**$4.67**
Forsyth	1,892	$4,525	$2.39	$115,273	716	**$25.47**
Fort Benton	1,460	$27,285	$18.69	$151,489	895	**$5.55**
Glendive	5,490	$21,344	$3.89	$315,661	1,987	**$14.79**
Great Falls	59,638	$565,383	$9.48	$563,816	8,610	**$1.00**
Hamilton	4,602	$13,703	$2.98	$240,429	1,639	**$17.55**
Harlowton	979	$5,992	$6.12	$196,974	1,080	**$32.87**
Havre	9,834	$52,848	$5.37	$622,384	3,554	**$11.78**
Helena	30,581	$229,715	$7.51	$1,284,720	9,385	**$5.59**
Judith Gap	125	$1,826	$14.61	$17,356	148	**$9.50**
Kalispell	22,052	$260,356	$11.81	$891,375	9,077	**$3.42**
Laurel	6,943	$200,497	$28.88	$628,740	3,361	**$3.14**
Lewistown	5,874	$45,776	$7.79	$439,269	2,665	**$9.60**
Libby	2,645	$5,400	$2.04	$135,322	1,751	**$25.06**
Livingston	7,307	$22,140	$3.03	$644,150	3,888	**$29.09**
Manhattan	1,631	$40,842	$25.04	$96,036	774	**$2.35**
Missoula	71,022	$400,342	$5.64	$2,482,612	22,537	**$6.20**
Polson	4,707	$36,659	$7.79	$202,732	1,584	**$5.53**
Red Lodge	2,222	$25,837	$11.63	$246,350	2,205	**$9.53**
Roundup	1,836	$31,406	$17.11	$307,540	1,548	**$9.79**
Shelby	3,268	$32,480	$9.94	$162,682	1,364	**$5.01**
Sidney	6,828	$12,699	$1.86	$308,222	2,125	**$24.27**
Stanford	381	$54,617	$143.35	$48,744	297	**$0.89**
Thompson Falls	1,332	$45,315	$34.02	$75,632	623	**$1.67**
Townsend	1,959	$8,005	$4.09	$114,690	997	**$14.33**
Valier	508	$1,321	$2.60	$76,253	564	**$57.72**
White Sulphur Springs	910	$3,260	$3.58	$57,573	492	**$17.66**
Whitefish	7,073	$49,234	$6.96	$340,775	3,474	**$6.92**
Whitehall	1,094	$7,800	$7.13	$56,312	422	**$7.22**
Total	**475,399**	**$3,271,621**		**$14,436,333**	**120,885**	**$4.41**

Other Statewide Assessments

While it is uncommon to perform an urban forest analysis at this scale, a few other statewide urban forest resource analyses do exist or are in progress. Indiana, Washington, and New York all have reported on their processes.

New York's assessment varied from the others in that it included both villages and cities, and did not discuss tree benefits, total trees or total species. For these reasons, it is not included in our comparative assessment. Indiana's inventory assessment differed from Montana's and Washington's in that it reported on a sample of each community, meaning just a portion of the communities' trees were used to create a representation of the tree population. Montana and Washington used complete tree inventories, meaning each public tree was individually measured and recorded.

Montana assessed the highest number of communities (61), but Indiana inventoried the highest number of trees (326,788 trees). Indiana's trees also provided the highest annual benefit at approximately $30 million, but the highest per-tree benefit is in Montana with $124 per tree. Washington has the highest number of unique species (330 species). All three of the communities' tree populations are reported to be in relatively good condition. More information about these communities is available in Table 16.

Table 16: Statewide Assessment Comparisons

Attribute	Montana	Indiana	Washington
Number of Communities	61	23	21
Total Trees	138,420	326,788	46,888
Average Trees/Community	2,269	14,208	2,232
Number of Unique Species	180	243	330
Most Prevalent Tree Species	green ash (20.3%)	silver maple (18%)	red maple (8.8%)
Condition	good (55%)	good (36%)	good (50%)
Age Distribution	Mostly Young 0-8 in DBH (48%)	Mostly Maturing 12-24 in DBH (30%)	Mostly Established 6-12 in DBH (29%)
Overall Benefit Value	$17,184,713	$30,000,000	$2,943,544
Per-Tree Benefit Value	$124.15	$91.80	$62.78
State Population (2016 estimated - U.S. Census)	1,042,520	6,633,053	7,288,000

In 2014, the United States Department of Agriculture (USDA) began an urban inventory program as part of its Forest Inventory and Analysis (FIA) due to legislative direction in the Farm Bill. Urban FIA is a plot-based inventory and monitoring system focusing on the largest cities in the US where approximately 80% of the population resides. Inventories will be continually refreshed so that planners can use the information to make informed decisions (USDA Forest Service Research and Development 2016). While work is underway on this program, no statewide reports have been published to date. Applying the FIA program's rigorous, systematic methods to future inventories could improve any comparison of city and state resources. No Montana cities have been inventoried by the Urban FIA program at its current capacity.

Conclusion

This analysis describes the current overall structural characteristics of Montana's community forest resources using established tree sampling, numerical modeling, and statistical methods to provide a general accounting of the benefits. The analysis provides a "snapshot" of this resource at its current population, structure, and condition. Rather than examining each individual tree, as an inventory does, a resource analysis examines trends and performance measures across the urban forest, or in this case across multiple community forests within the state, and for each of the predominant species populations within. The goals of the assessment were to:

- Determine the current composition and condition of Montana's community forests
- Quantify the ecosystem services Montana's community forest provides
- Provide an improved understanding of the community forest and the benefits it provides to the general public and public officials
- Identify new opportunities to increase benefits to communities and the state of Montana

Across the state of Montana, community trees are providing quantifiable impacts on air quality, reduction in atmospheric CO_2, stormwater runoff, and aesthetic benefits. The 138,420 community trees are providing over $17.2 million in annual gross benefits, an average of $124.15 per tree.

At the state level, community forests in Montana have a nearly ideal age distribution of young, established, and mature trees in good condition. More than 180 different species are documented, however the species diversity of several communities with large ash populations should be improved in preparation for the arrival of emerald ash borer. Each community can increase the benefits from their individual urban forest by using all available planting sites to increase the stocking level (currently 87.9% overall) as well as by replacing mature trees that are in decline and recommended for removal (3.6% overall). Communities should continue to focus resources on preserving existing and mature trees to maintain health, improve structure, promote tree longevity, and manage risk. Structural pruning and training young trees will reduce long-term maintenance costs and ensure proper form as trees mature. Davey Resource Group recommends the following:

- Increase species diversity to ensure that new tree plantings include a variety of suitable species and do not rely on prevalent species.
- Increase stocking level by using all available planting sites and plant large-stature species wherever space allows.
- Provide structural pruning for young trees and a regular pruning cycle for all trees.
- Protect existing trees and manage risk with regular inspection to identify and mitigate structural and age-related defects.
- Continue to maintain and update the inventory database, including tracking tree growth and condition during regular pruning cycles.

In addition, Montana DNRC can help to further the benefits of trees and urban forestry by providing the following services to communities:

- Continue providing support for community forestry programs with technical assistance, financial assistance, public education and volunteer coordination.
- Continue to inventory communities to develop a more complete picture of Montana's community forests.
- Develop a general Urban and Community Forestry Program plan. Work with individual communities to plan for their specific needs.

- Encourage communities to understand the important distinction between forestry and urban forestry, and help them to develop proactive urban forest maintenance plans.
- Further explore the inventory by sub-regions to find additional trends that might encourage maintenance practices.

Community forest managers can better anticipate future trends with an understanding of their communities' tree conditions. Managers can also anticipate challenges and devise plans to increase benefits. Performance data from this analysis can help make determinations regarding species selection, distribution, and maintenance policies. Documentation of current structure is necessary for establishing goals and performance objectives, and can serve as a benchmark for measuring future success. Information from this analysis can be referenced in the development of an urban forest management or master plan. An urban forest master plan inspires commitment, provides tools for communication with key decision-makers and informs communities about their current urban forest baseline and future goals and challenges. The next steps are determining the desired outcomes and how to accomplish these outcomes. Considerations should include:

- Development of management plans – at the state and community levels. These plans will utilize existing resources to reach goals
- Maintenance of the inventory – keep it live and ongoing, rather than a snapshot. Utilize TreeKeeper 7.7, the state's new inventory management system
- Initiation of training – starting 2017, local communities will have the ability to update and manage their own urban forest inventories using DNRC's TreeKeeper 7.7 system, and between DNRC and DRG plenty of opportunities exist to train staff on the use of this software, whether it be onsite or remotely.
- Public awareness (locally, and statewide) – Share the inventory factsheets with city council, tree boards, or organizations that should be aware of tree benefits. Share the executive summary at the state level to further educate and raise awareness.
- Currently, inventoried communities have 1 tree per 3 people. As an initial goal, aim to reverse that with 3 trees per person.

Montana's community trees are imperative to the environmental, social, and economic well-being of the community. The state has demonstrated that public trees are a valued community resource, a vital component of the urban infrastructure, and an important part of Montana's history and identity (Figure 27). The inventory data can aid in planning a proactive approach to the future care of community trees. Inventory updates should continue as regular maintenance is performed, including updating the DBH and condition of existing trees. Current and complete inventory data will help local and state managers more efficiently track maintenance activities and tree health, and will help inform management decisions. A continued commitment to planting, maintaining, and preserving these trees will support the health and welfare of the state and the surrounding region.

Figure 27. City of Whitefish Arbor Day Celebration. Community trees are an important part of Montana's history and identity. Every April students learn how trees benefit their community and future generations at Arbor Day tree plantings.

Appendix A: Methodology

Between 2007 and 2015, DNRC technicians or certified arborists conducted inventories of publicly-owned street and right-of-way trees in 61 communities across the State of Montana. The inventories included details about each tree's species, size, and condition. To determine the overall structure and benefits of community trees in Montana, the inventory data was formatted for use in Treekeeper® version 7.7 and MyTreekeeper®, tree management and assessment tools developed by Davey Resource Group. Treekeeper® version 7.7 was designed to be highly customizable, allowing the user to connect various tree attributes and types of information to it per project specifications. Matrix reports, generated by Treekeeper® provided the data for structural analysis, include species prevalence, condition ratings, and age distribution. MyTreekeeper®, which used the National Tree Benefits Calculator (treebenefits.org), provided data on environmental, aesthetic, and socioeconomic benefits as well as tree value estimates. The National Tree Benefits Calculator is based on i-Tree STREETS. It uses the same base values as i-Tree STREETS, a peer-reviewed software suite from the USDA Forest Service, to calculate benefits. These tools were used in combination to assess tree population structure and function, including the role of trees in reducing energy use, air pollution removal, stormwater interception, carbon dioxide removal, and property value increases. To analyze the economic benefits of Montana's community trees, MyTreekeeper® was used to calculate the dollar value of annual resource functionality. This analysis considered all the inventoried community tree populations as a whole to develop an assessment of statewide trends and benefit modeling regarding the structure, function, and value of the overall resource.

An annual resource unit was determined on a per tree basis for each of the modeled benefits. Resource units are measured as MWh of electricity saved per tree; therms of natural gas conserved per tree; pounds of atmospheric CO_2 reduced per tree; pounds of NO_2, SO_2, O_3, PM_{10}, and VOCs reduced per tree; cubic feet of stormwater runoff reduced per tree; and square feet of leaf area added per tree to increase property values.

Price values assigned to each resource unit were generated based on economic indicators of society's willingness to pay for the environmental benefits trees provide. Communities that report an annual budget to Tree City USA provided estimated investment costs for contracted and in-house tree services, pest management, administration, and inspections.

Tree Condition ratings were used in the calculation of annual benefits. Condition ratings for this analysis are defined as the condition of the wood:

Good- Greater than 85% of a tree's wood is alive and circumference of the trunk has bark. The tree is in good health with no defects which will affect the tree's longevity. Form is characteristic of the species.

Fair- Dieback of 15-50% of small branches; or 1-2 large branches dead; or 15-50% of trunk circumference dead; or fruiting bodies present.

Poor- Dieback of 50-90% of small branches, 3 or more major branches dead and priority pruning is required. 50-90% of trunk circumference dead, decayed and/or hollow.

Dead or Dying- Less than 10% of the tree's wood is alive. Likelihood for saving the tree is minimal or non-existent, or tree is currently dead.

Estimates of benefits are initial approximations as some benefits are difficult to quantify (e.g. impacts on psychological health, crime, and violence). In addition, limited knowledge about the physical processes at work and their interactions makes estimates imprecise (e.g., the fate of air pollutants trapped by trees and then washed to the ground by rainfall). Therefore, this method of quantification provides first-order approximations based on current research. It is intended to be a general accounting of the benefits produced by urban trees.

Appendix B: Glossary of Terms

Benefit-Investment Ratio – the remaining benefits once the expenditures are removed from the total benefits

Carbon avoidance – the amount of carbon prevented from being released into the atmosphere due to heating and cooling reductions

Carbon sequestration – the removal of carbon dioxide from the air by plants

CO_2 – carbon dioxide

Diameter at Breast Height (DBH) – the diameter of the tree measured 4 ft., 6 in

Leaf surface area – the distribution of leaves in a tree (both horizontal and vertical). This is an area calculation, which differs from canopy cover as it includes vertical area and canopy overlap

NO_2 – nitrogen dioxide

O_3 – ozone

PM_{10} – particulate matter less than 10 microns and greater than 2.5 microns

Relative age distribution – the distribution of trees based on their diameter class, which determines their relative age

Replacement value – the cost to replace a tree with another of a similar size, species, and condition

SO_2 – sulfur dioxide

Stocking level – trees per available space

Stormwater runoff – rainfall that is unable to percolate the ground or otherwise be intercepted

Ton – short ton (U.S.), 2,000 pounds

Tree condition – a determination of how trees are performing in a site

Appendix C: References

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Appendix D: Species Index

Common Name	Scientific Name
Balsam fir	Abies balsamea
White fir	Abies concolor
Fraser fir	Abies fraseri
Grand fir	Abies grandis
Subalpine fir	Abies lasiocarpa
Fir spp.	Abies species
Hedge maple	Acer campestre
Amur maple	Acer ginnala
Rocky Mountain maple	Acer glabrum
Bigtooth maple	Acer grandidentatum
Paperbark maple	Acer griseum
Boxelder	Acer negundo
Black maple	Acer nigrum
Japanese maple	Acer palmatum
Norway maple	Acer platanoides
Norway maple 'Schwedler'	Acer platanoides 'Schwedleri'
Sycamore maple	Acer pseudoplatanus
Red maple	Acer rubrum
Silver maple	Acer saccharinum
Sugar maple	Acer saccharum
Maple spp.	Acer species
Tatarian maple	Acer tataricum
Freeman maple	Acer x freemanii
Ohio buckeye	Aesculus glabra
Common horsechestnut	Aesculus hippocastanum
Red horsechestnut	Aesculus x carnea
Alder spp.	Alnus species
Serviceberry spp.	Amelanchier species
Yellow birch	Betula alleghaniensis
River birch	Betula nigra
Paper birch	Betula papyrifera
White birch	Betula pendula
Gray birch	Betula populifolia
Birch spp.	Betula species
Broadleaf Deciduous Large	Broadleaf Deciduous Large
Broadleaf Deciduous Medium	Broadleaf Deciduous Medium
Broadleaf Deciduous Small	Broadleaf Deciduous Small
Broadleaf Evergreen Large	Broadleaf Evergreen Large
Broadleaf Evergreen Medium	Broadleaf Evergreen Medium
Broadleaf Evergreen Small	Broadleaf Evergreen Small

Common Name	Scientific Name
European hornbeam	Carpinus betulus
American hornbeam	Carpinus caroliniana
Shagbark hickory	Carya ovata
Hickory spp.	Carya species
Catalpa spp.	Catalpa species
Northern catalpa	Catalpa speciosa
Common hackberry	Celtis occidentalis
Eastern redbud	Cercis canadensis
Conifer Evergreen Large	Conifer Evergreen Large
Conifer Evergreen Medium	Conifer Evergreen Medium
Conifer Evergreen Small	Conifer Evergreen Small
Dogwood spp.	Cornus species
Turkish filbert	Corylus colurna
Smoketree	Cotinus coggygria
Washington hawthorn	Crataegus phaenopyrum
Hawthorn spp.	Crataegus species
Russian olive	Elaeagnus angustifolia
Beech spp.	Fagus species
European beech	Fagus sylvatica
White ash	Fraxinus americana
European ash	Fraxinus excelsior
Manchurian ash	Fraxinus mandshurica
Black ash	Fraxinus nigra
Green ash	Fraxinus pennsylvanica
Fraxinus spp.	Fraxinus species
Ginkgo	Ginkgo biloba
Honey locust	Gleditsia triacanthos
Kentucky coffeetree	Gymnocladus dioicus
American holly	Ilex opaca
Butternut walnut	Juglans cinerea
Black walnut	Juglans nigra
Chinese juniper	Juniperus chinensis
Common juniper	Juniperus communis
Cherrystone juniper	Juniperus monosperma
Rocky Mountain juniper	Juniperus scopulorum
Juniper species	Juniperus species
Eastern redcedar	Juniperus virginiana
European larch	Larix decidua
Western larch	Larix occidentalis
Larch spp.	Larix species
Sweetgum	Liquidambar styraciflua
Tulip tree	Liriodendron tulipifera
Honeysuckle spp.	Lonicera species

Common Name	Scientific Name
Amur maackia	Maackia amurensis
Southern magnolia	Magnolia grandiflora
Common apple	Malus pumila
Crabapple spp.	Malus species
Dawn redwood	Metasequoia glyptostroboides
Red mulberry	Morus rubra
American hophornbeam	Ostrya virginiana
Amur corktree	Phellodendron amurense
Norway spruce	Picea abies
Engelmann spruce	Picea engelmannii
White spruce	Picea glauca
Black spruce	Picea mariana
Colorado blue spruce	Picea pungens
Red spruce	Picea rubens
Sitka Spruce	Picea sitchensis
Spruce spp.	Picea species
Bristlecone pine	Pinus aristata
Jack pine	Pinus banksiana
Swiss stone pine	Pinus cembra
Lodgepole pine	Pinus contorta
Bolander pine	Pinus contorta 'bolanderi'
Pinyon pine	Pinus edulis
Limber pine	Pinus flexilis
Western white pine	Pinus monticola
Mugo pine	Pinus mugo
Austrian pine	Pinus nigra
Ponderosa pine	Pinus ponderosa
Pitch pine	Pinus rigida
Pine spp.	Pinus species
Southwestern white pine	Pinus strobiformis
Eastern white pine	Pinus strobus
Scotch pine	Pinus sylvestris
London planetree	Platanus hybrida
White poplar	Populus alba
Narrowleaf cottonwood	Populus angustifolia
Balsam poplar	Populus balsamifera
Black cottonwood	Populus balsamifera ssp. trichocarpa
Eastern cottonwood	Populus deltoides
Fremont cottonwood	Populus fremontii
Bigtooth aspen	Populus grandidentata
Lombardy poplar	Populus nigra
Lombardy poplar	Populus nigra 'italica'
Sargent poplar	Populus sargentii

Common Name	Scientific Name
Populus spp.	Populus species
Quaking aspen	Populus tremuloides
Lanceleaf cottonwood	Populus x acuminata
Carolina poplar	Populus x canadensis
Apricot spp.	Prunus armeniaca
Cherry plum	Prunus cerasifera
Amur chokecherry	Prunus maackii
European bird cherry	Prunus padus
Pin cherry	Prunus pensylvanica
Black cherry	Prunus serotina
Cherry spp.	Prunus species
Common chokecherry	Prunus virginiana
Shubert chokecherry	Prunus virginiana 'Shubert'
Douglas-fir	Pseudotsuga menziesii
Pear spp.	Pyrus species
White oak	Quercus alba
Swamp white oak	Quercus bicolor
Scarlet oak	Quercus coccinea
Northern pin oak	Quercus ellipsoidalis
Bur oak	Quercus macrocarpa
Chinkapin oak	Quercus muehlenbergii
Water oak	Quercus nigra
Pin oak	Quercus palustris
English oak	Quercus robur
Red oak	Quercus rubra
Oak spp.	Quercus species
Black oak	Quercus velutina
Common buckthorn	Rhamnus cathartica
Smooth sumac	Rhus glabra
Sumac spp.	Rhus species
Staghorn sumac	Rhus typhina
Black locust	Robinia pseudoacacia
White willow	Salix alba
Pussy willow	Salix discolor
Crack willow	Salix fragilis
Black willow	Salix nigra
Willow spp.	Salix species
Weeping willow	Salix x sepulcralis Simonkai
American mountain-ash	Sorbus americana
European mountain-ash	Sorbus aucuparia
Mountain-ash	Sorbus species
Japanese tree lilac	Syringa reticulata
Lilac spp.	Syringa species

Common Name	Scientific Name
American arborvitae	Thuja occidentalis
Western redcedar	Thuja plicata
Cedar spp.	Thuja species
American linden	Tilia americana
Little-leaf linden	Tilia cordata
Linden spp.	Tilia species
American elm	Ulmus americana
Chinese elm	Ulmus parvifolia
Siberian elm	Ulmus pumila
Elm spp.	Ulmus species
Viburnum spp.	Viburnum species
Chinese wisteria	Wisteria sinensis

Appendix E: Emerald Ash Borer

The emerald ash borer (EAB) is an invasive beetle that has killed hundreds of millions of trees in eastern North America. The beetle was discovered near Detroit, Michigan in 2002. It was most likely imported into the U.S. from Asia, where it is native, via solid wood packing material. As of 2016, EAB has been detected in twenty-eight states and two Canadian provinces, but has not been detected in Montana. Since ash trees occur in nearly all of Montana towns, consideration of this major pest threat requires attention.

Green Ash is the Most Abundant Urban Forest Tree in Montana

EAB larvae feed on the inner bark of all species of ash trees (*Fraxinus spp*.) and inhibit trees' ability to transport water and nutrients. Adults can generally fly two miles in search of a suitable host (Taylor et al., 2006), but the primary means of dispersing great distances has been by human transport of nursery stock, wood packing material, and firewood. All infested trees die if not properly treated with insecticides. Montana is a popular hunting and recreation destination which corresponds with high volumes of out-of-state firewood being brought in. It is estimated that there are approximately 235,000 opportunities a year for the importation of EAB-infested ash firewood into Montana (Foley, 2012). Preventing the introduction of EAB requires close monitoring of the potential host material that enters Montana. To date, there are no regulations in effect that restrict firewood movement into Montana. In states where EAB occurs, the United States Department of Agriculture and state regulatory agencies have enforced quarantines and fines to prevent potentially infested ash trees, logs, or firewood from moving out of infested areas.

EAB has imposed a tremendous financial burden on municipalities, property owners, nursery operators and forest products industries. If/when EAB is detected in Montana, its consequences could be severe. Overall, ash comprises approximately 29% of all public trees planted in Montana communities. Five separate species have been reported by the Montana Department of Natural Resources and Conservation (DNRC) urban tree inventory—green ash (*Fraxinus pennsylvanica*), which is native to eastern Montana, European ash (*Fraxinus excelsior*), Manchurian ash (*Fraxinus mandshurica*), white ash (*Fraxinus americana*), and black ash (*Fraxinus nigra*). EAB has the potential to drastically change our communities by killing ash trees that beautify our downtowns and neighborhoods, provide shade, regulate stormwater runnoff, improve air quality, and reduce energy costs.

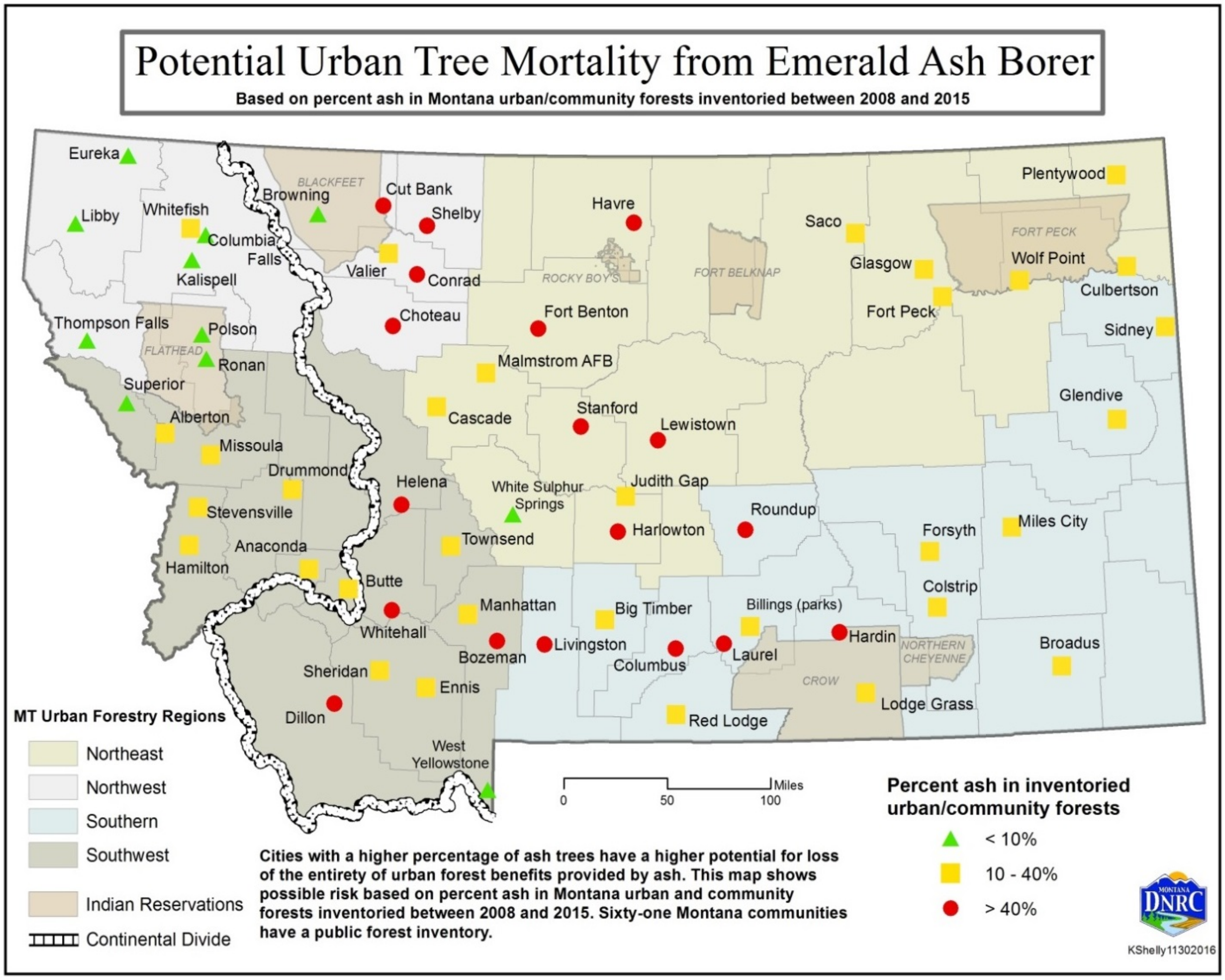
Ash is the most commonly planted tree in several Montana communities east of the Continental Divide. The DNRC urban tree inventory calculated that ash represents more than 50% of all publicly-owned trees in 12 communities: Havre, Roundup, Laurel, Columbus, Stanford, Conrad, Fort Benton, Dillon, Harlowton, Hardin, Lewistown, and the state capital, Helena (Table 17). These communities have the most to lose when emerald ash borer arrives. Figure 29 maps the potential ash mortality in communities with a tree inventory. Communities with higher percentages of ash have a higher potential for loss of urban forestry benefits provided by those trees. Of 61 inventoried communities:

- 11 have 10% or less of their public urban tree population as ash, and will suffer the least consequences if an infestation occurs.
- Thirty-two communities have between 10 and 40% ash.
- 18 have over 40% of their community forest in ash species, and are at risk of losing a significant portion of their community forest (Table 17).

In addition to losing the economic and aesthetic benefits, communities with more ash will also incur high expenditures for tree removal and replacement.

Montana Communities with over 40% Ash

2015 Statewide Ash Summary (>40% Ash) (Communities sorted in descending order of percent ash)				
Inventoried Community*	Year(s) Inventoried	No. Ash Trees	No. Trees Inventoried	Percent Ash
Havre	2012	2501	3554	70
Roundup	2010, 2014	1088	1548	70
Laurel	2011	2292	3361	68
Columbus	2014	818	1202	68
Stanford	2012	198	297	67
Conrad	2014	795	1204	66
Fort Benton	2012	575	889	65
Dillon	2011	494	781	63
Harlowton	2014	651	1086	60
Helena	2010	5551	9330	60
Lewistown	2012	1489	2655	56
Hardin	2014	518	997	52
Cut Bank	2012	283	577	49
Bozeman	2010-2013	4912	10529	47
Livingston	2009-2014	3546	7778	46
Whitehall	2012	188	422	45
Shelby	2013	558	1364	41
Choteau	2012	547	1356	40



Percent Ash and Potential Urban Tree Mortality from EAB in Montana Inventoried Community Forests

DNRC is preparing for a detection of emerald ash borer and evaluating appropriate management options. The Emerald Ash Borer Readiness and Response Plan (Gannon, et al., 2015) outlines Montana DNRC's approach to EAB prevention, detection, eradication, communication and community forest restoration. DNRC will work in conjunction with federal, state, tribal, university, community, and private partners to establish collaborative efforts for effective responses as an infestation emerges. Specific tactics will change over time as policies are developed and science advances. Thus, this document will be periodically revisited and updated. Any response will incorporate multi-agency involvement.

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