Dollars and Sense:

An Evaluation of Ecosystem Services Provided by Spencer's Butte Park

Erik George Forsell—NABCEP

Master of Community and Regional Planning, June 2014

Abstract

Ecosystem services are often described as the biophysical environment that provide humans and the surrounding habitat with natural, ecological and environmental resources and benefits. Ecosystem services include a wide variety of benefits such as air quality, carbon sequestration, storm water retention, and nutrient cycling; however, they can also refer to a management approach or decision-making process for managing these types of resources.

Ecosystem services provide an intrinsic value that has been detailed in recent reports to exceed the value of the entire world's annual Gross Domestic Product (GDP) revenue. In one of the most widely cited ecosystem service valuation studies, researchers in 1997 estimated that the value of services provided by Earth's ecosystems was at least 33 trillion U.S. dollars, compared to the global (GDP) of approximately 17 trillion dollars at the time. Capital valuation builds an easier understanding about the economic and ecological benefits that are accrued through ecological functions in the environment. Much of the benefits that are realized by humans as a result of ecosystem services are manifested in the form of cost avoidance to storm water infrastructure, provisioning materials such as lumber and foodstuffs, and health benefits such as cleaner drinking water, and reduced air pollution.

The research in this report evaluates air quality and carbon sequestration ecosystem services at Spencer's Butte in Eugene, Oregon. Discussed within is a description of typical ecological services and a portrayal of the unique ridgeline habitats found just south of Eugene, Oregon. The analysis included within this research utilizes a popular and commonly used ecosystem service modelling tool—***iTree Vue***. The modelling software utilizes land use data, canopy and herbaceous layer composition, and impervious surface descriptions to evaluate ecosystem services on a landscape scale. The findings from the model describe quantification in dollar values of the ecological air quality benefits provided by vegetated habitats on Spencer's Butte.

Dollars and Sense: An Evaluation of Ecosystem Services Provided by Spencer's Butte in Eugene, Oregon

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Chapter 1: Introduction

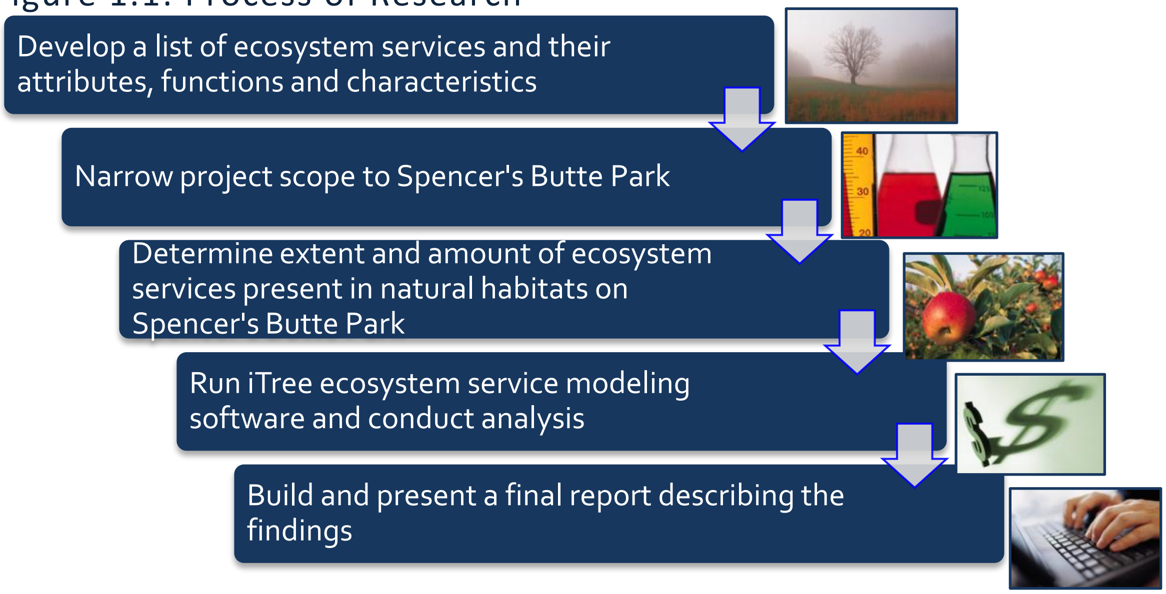
The purpose of this research is to evaluate ecosystem services that provide benefits to air quality and carbon sequestration in the city of Eugene's Spencer's Butte Park. The report seeks to answer **four** questions about ecosystem services as well as provide a framework for broadening the discussion for the City of Eugene and academia about the value of ecosystem services that are **generally taken for granted.**

Research Questions

1. What are important and quantifiable ecosystem services?
2. What are established and agreed upon methodologies for evaluating and quantifying air quality ecosystem services in different monetary and intrinsic values?
3. What are the spatial and quantifiable air quality and carbon sequestration ecosystem services present in the city of Eugene's Spencer's Butte Park?
4. When applying the established methodologies of ecosystem service evaluation to known park and open space natural resources what is the range of quantifiable ecosystem services found in dollar amounts for air pollution reduction?

The process of the research follows an order that began with collecting data, information and expert opinions about ecosystem services. After data, were analysed and synthesized the project scope was narrowed to focus on air quality ecosystem services at Spencer's Butte Park. Lastly, an ecosystem services modelling software was used to determine capital values for ecosystem services provided by the natural habitats found on Spencer's Butte. **Figure 1.1** displays the process of the research.

Figure 1.1: Process of Research



Overview of Research

The intent of this research is to explore and evaluate the ecosystem services related to the promotion of air quality at Spencer's Butte Park in Eugene, Oregon. To achieve an understanding about the capital valuation of air quality promoting ecosystem services the research seeks to develop an understanding of what types of habitats exist at Spencer's Butte Park and the ecological amenities that are present within the park.

Ultimately, the focus of the research is to evaluate ecosystem services related to air quality and to quantify those benefits to humans and the natural environment in dollar values. This is achieved by developing an understanding of Spencer's Butte and how it mitigates, improves and assists in providing greater air quality for the region. The research also includes an exploration of the various types of air quality promotion aspects including the ability to remove pollutants and toxins from the air and the ability of vegetation to store and sequester carbon.

Lastly, this research attempts to build an argument for the importance of preserving the vegetated habitats that produce a variety of positive externalities that proceed largely unnoticed and to bring to the forefront the importance of protecting, restoring and maintaining unique habitats found within the Eugene, Oregon area. The end product of the research is information about ecosystem services, a range of quantifiable dollar amounts for specific air quality related services and a suite of recommendations and conclusions derived from the data and methodology found within this report.

Why Spencer's Butte?

The value of focusing on Spencer's Butte in Eugene is multi-fold.

- Conducting analysis on a smaller spatial area is a more manageable task given time and resources for this project.
- Ecosystems tend to reside within what are called 'bio-regions'; therefore what may exist in North Carolina will likely be considerably different in The Willamette Valley.
- The habitat types found at Spencer's Butte are a relatively unique and disparate habitat type in the region and the presence of native and rare habitat types such as oakland savannah and mixed conifer forests provide for a special opportunity to evaluate an important ecological resource in the Eugene, Oregon area.
- Staff at the City of Eugene Parks and Open Space department are actively attempting to build a case for additional funding for its programs because of a strong belief that the parks, open space and vegetation found on city property plays an integral role in the mitigation of water and air quality related issues in the area.
- Air quality is also guided and monitored by the (EPA) and the Lane Regional Air Protection Agency (LRAPA) oversees air quality measurement data in Lane County. The Amazon Creek air quality location is in relative close proximity to Spencer's Butte and provides relevant secondary data about air quality for the research.

Importance of Research

Ecosystem services provide an intrinsic value that has been described in recent reports to exceed the value of the entire world's annual Gross Domestic Product (GDP) revenues. In one of the most widely cited ecosystem service valuation studies, researchers in 1997 estimated that the value of services provided by Earth's ecosystems was at least 33 trillion U.S. dollars, in comparison to the global (GDP) of approximately 17 trillion dollars at the time.[1] This valuation suggests that the significance of the maintenance and protection of habitats and ecosystems that provide the vast array of ecosystem services is of the utmost importance. Much of the benefits that are seen from ecosystem services are in the form of cost avoidance to infrastructure, provisioning materials such as lumber and foodstuffs, and health benefits such as cleaner air and water.

One of the primary reasons for attempting to place quantifiable dollar values to ecosystem services is that the information can be used as a hard data source that brings a stronger argument for the importance of maintaining and restoring the natural ecosystems in our communities. The data can also suggest that through the maintenance and proper management of ecosystems and habitats, especially those with strong ecosystem services—that cities, private individuals and the community at large can reap large benefits from the habitats surrounding cities, homes and development.

The analytical model outputs from this research directly inform this report which details the air quality and ecosystem services in Eugene's Spencer's Butte Park and quantifies in dollar amounts the value of those services provided to the city and its residents. Ultimately, the research will seek to fill a 'gap' in the understanding of the ecosystem services present at Spencer's Butte Park. The information presented in this research can also serve as a guide for engaging the public about ecosystem services or to begin building a data set of reports that describe the ecological functions present in the parks an open space areas of Eugene. Additionally, the South Ridgeline Habitat areas such as Spencer's Butte are unique environmental and cultural resource that is frequently used for recreation—building a data set and case for the importance of such an area could be more useful than a project site that is not as well know within the community.

[1] Costanza et al. (1997). *The Value of The World's Ecosystem Services and Natural Capital.* Nature. 387: 253-260.

Ecosystem Services on Public Land

Ecosystem services provide an valuable service that is often taken for granted by the public because much of the land and habitat that provides these services are lands that are held in 'commons'. This project begins to start the discussion of valuing a resource and services that is not easily discussed in monetary values. This creates a disconnection and lack of awareness about ecosystem services and the benefits that are conveyed such as: cost saving avoidance, environmental protection, health benefits and other important activities that are rarely quantified or effectively recognized for their important contribution to a variety of important ecological functions. Much of the ecosystem service functions derived from the environment happen day-to-day without appreciation from the residents in the area or various components of the municipal government. Using data, information and established methodology to place capital value amounts to the ecosystem services found on land in parks and open space will enable cities and administrations to express the importance for providing adequate funding and support to the park and public works departments in any particular city.

The recognition of ecosystem services and the many values the ecological functions provide are often taken for granted because much of the lands that provide these services are public or land held in commons. Such is the case with the parks and open space in Eugene. At present (2014), there are additional plans to evaluate the ecosystem services in Eugene's parkland and open space—this research seeks to provide a gap in understanding of ecosystem service evaluation in the Eugene area. This suggests the growing importance for the quantification of ecosystem services in dollar values as an important tool for building a case for the protection and improvement of ecological areas that provide measurable benefits to humans and the natural environment.

Organization of This Document:

The report contains the following major sections with additional materials found in the appendices of the document.

Chapter 2: Ecosystem Services

- Provides an overview of the general concepts and categories of the broad spectrum of ecosystem services.
- Details biophysical ecosystem services and how they promote air quality and carbon sequestration

Chapter 3: Spencer's Butte Park

- Describes the types, quantity and spatial attributes of habitats and ecological amenities at Spencer's Butte Park.

Chapter 4: Air Quality

- Describes the types of air pollutants, provides information about the EPA air quality act, and county data from the regional air authority (LRAPA) Lane Regional Air Protection Agency about air quality in the region.

Chapter 5: Methodology

- Describes the methodological approach for evaluating the air quality and carbon sequestration ecosystem services present at Spencer's Butte Park.

Chapter 6: Findings

- Overviews the findings from the iTrees modeling software and other anecdotal information discovered during the research process.

Chapter 7: Conclusions / Recommendations

- Provides a suite of conclusions and recommendations for further research and use.

Appendix: A / B / C

- Describes the limitations of the iTrees modelling software in detail.
- List of ecosystem service modelling software's
- Info graphics describing common and important ecosystem services.

Chapter 2: Ecosystem Services

Ecosystem services are the conditions and processes through which natural ecosystems and the species that make comprise, sustain and fulfill human life[2]

Photograph Source: Steve Rafuse

The predominant literature in this field is in the form of professional reports, city and municipal reports, white papers and consultant reports. However, much of this literature has been adequately vetted through the scientific and economic community, it is often adequately corroborated because of the nature of the material's scientific based legitimacy and continued support from cities across the Pacific Northwest and United States. The material in this chapter describes the following components:

- An overview and general description of literature describing ecosystem services.
- A description of physical and bio-physical ecosystem services.
- A description of air quality ecosystem services
- A description of carbon sequestration ecosystem services

[2] Pejchar, L, P Morgan, M Caldwell, C Palmer, and GC Daily. *Evaluating the potential for conservation development: Biophysical, economic, and institutional perspectives.* Conservation Biology 21(1): 69-78. (2007).

Overview of Ecosystem Services

The concept of ecosystem services was originally described in the early 1970s coinciding with a growing political and ecological movement that recognized the extreme damage that was caused as a result of the over exploitation of our world's natural habitats and ecosystems.[3] The term ecosystem services is often an ambiguous definition for a complex idea; it requires a multi-level and holistic approach for understanding its meaning.

Ecosystem services are often described as the biophysical environment that provide humans and the surrounding habitat with natural resources, environmental resources, and ecological resources. The services are often defined as a suite of goods such as pollination, air quality promotion, storm water retention, carbon sequestration, and nutrient cycling but can also refer to a management approach or decision-making process for managing these types of resources.[4]

Ecosystem services and the quantification of those services into capital dollar amounts is a relatively new field of understanding. For example, a recent Earth Economics report evaluating the Puyallup Watershed in Washington State suggested that, "Ecological economics is a recent advancement in economics and provides an integrated approach to managing a watershed's economy and ecosystems."[5] Earth Economics is a consulting firm in the Pacific Northwest that evaluates the economic value of ecosystem services in the region. The consulting firm is apt to suggest that although they are confident in the products and analysis they produce, the firm recognized and attempts to account for the relative novelty of the methodologies evaluating natural environments. Capital valuation of ecosystem services is a cutting-edge field that uses a variety of scientific techniques, measurements, observations and data to quantify services such as turbidity reduction or smaller citywide heating day degree figures.

The purpose and scope of this report focuses on the environmental benefits (physical and biological) of ecosystem services rather than the societal, recreational or cultural benefits. This is not to say that the societal, recreational and cultural benefits are not a vital component of the entire package of ecosystem services; however these benefits are significantly more challenging to quantify and understand. Additionally, the environmental benefits are critical for municipality decision makers to

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[3] North Carolina State University A&T Cooperative Extension. (2007). *Urban Waterways: Stormwater Wetlands and Ecosystem Services.* 1-8. Durham, North Carolina

[4] Enright, C. *Dissertation on Ecosystem Services.* 8-9. (2013).

[5] Earth Economics. *The Pullyup River Watershed: An Ecological and Economical Characterization.* (2011). Tacoma, Washington.

realize and manage or create policy decisions that accurately reflect value-based decisions about habitats that provide positive benefits to the area around the habitat. Often ecosystem services provide vast and unique benefits to cities and governments across the globe in the terms of cost avoidance to the stormwater infrastructure, pollination to crops, and recreational benefits to the residents in a municipality. Unfortunately, these benefits are often not adequately described or accounted for and thus are assumed as a benefit without a cost or necessity to maintain the habitats that provide the services.

Valuation and Cost Avoidance

Despite the nature of the field's relative new acceptance, the literature and professionals also suggest that ecosystem services have always manifested themselves in many ways whether they have been recognized or not. These manifestations are typically defined as *environmental benefits*: flood reduction, air quality promotion, storm water storage, carbon sequestration and habitat protection—more recently the scope has expanded to include economic items such as cost avoidance.

Cost avoidance is usually absorbed by local utilities and cities that can avoid the construction of additional infrastructure to mitigate potential issues such as turbidity in drinking water or fines for non-attainment of air quality standards in a particular air basin. However, cost avoidance can be realized on a smaller scale such as the hedonic value received from a densely planted garden or untouched forest on private property. Cost avoidance can also be realized from the health benefits (physical and mental) from an attractive park surrounding their property.

Cost avoidance can also be realized in more ambiguous and esoteric terms such as if a forest were removed how would that cause air quality to be impacted and on average how would the removal affect the air quality for individuals in an area. This type of quantification is relatively abstract but it begins to develop the framework for discussing the reasons and methods for dollar valuation of ecosystem services. Ecosystem services are also valuated on their cultural and recreational benefits that are commonly attributed to land such as parks, trails and wilderness.

Types of Ecosystem Services

There are many ways of describing and categorizing the categories of ecosystem services created from a diverse field experts that includes: economists, landscape architects, ecologists, engineers, arborists and planners. This section *describes the opinions of professional, scientific and economically categorized forms of ecosystem service*.

Ecosystem services are greatly varied and can be characterized in a variety of ways, and are omnipresent in the natural world. Ecosystem services are the benefits humans, communities and the natural world derive actively or passively from ecosystems, such as: provisioning services (wood, water, fish and medicinal compounds), cultural services (tourism, sports and research) and regulating services (climate stabilization, flood regulation, pollination and soil formation).[6]

Earth Economics, which relies upon the *Millennium Ecosystem Assessment Goals of 2005,* as well as ecosystem service valuation literature, describes ecosystem services as goods, provisions and services that economists and ecologists created for the United Nations. These services fall into four categories (regulating services, provisioning services, information services and habitat services). These four categories are further detailed in Figure 2.1 below:

Figure 2.1—Earth Economics Ecosystem Services Categorization[7]

Regulating Services	*Contains benefits obtained from the natural control of ecosystem processes. Intact and healthy ecosystems provide regulation of climate, water, soil, flood and storms, and keep disease organisms in check.*
Provisioning Services	*Provide basic goods including food, water and materials. Forests grow trees that can be used for lumber and paper, wild and cultivated crops provide food, and other plants may be used for medicinal properties or for manufacturing processes such as rubber. Rivers and lakes provide water for drinking and fish for food. The coastal waters provide fish, shellfish and seaweed.*
Information Services	*Allow humans to have meaningful interaction with nature. These services include cultural and spiritual values. These services also include significant species, natural areas, places for recreation and educational opportunities through science and observation.*
Habitat Services	*Provide refuge and reproduction habitat for wild plants and animals and thereby contribute to the conservation of biological and genetic diversity and the important natural ecological processes.*

The Common International Classification of Ecosystem Services described by the Pan Parks Foundations defines ecosystem services as the regulation and maintenance of the ecological world as

[6] Pan Parks Foundation. *The Economics of Wilderness.* (2012). Europe.

[7] Earth Economics. *The Pullyup River Watershed: An Ecological and Economical Characterization.* (2011). Tacoma, Washington.

well as a system that provides provisions in the form of materials and energy. This classification is a commonly used categorization tool that has been adapted by organizations across the world as a tool for ecosystem categorization. Figure 2.2 below describes the *Common International Classification of Ecosystem Services* and provides examples of how they these types of ecosystems services work in an environment.

Figure 2.2—Common International Classification of Ecosystem Services[8]

Regulation of Waste	*These services are described as the bioremediation of waste such as nitrates, phosphates, fecal coliform and other materials from the water, soils and ambient air of an area. It also describes the dilution of toxins, and other substances as well as the sequestration of carbon and other materials.*
Regulation of Flow	*The flow regulation of water is an extremely important ecosystem service and works in the form of increased water percolation and infiltration into the water table, reduction and filtration of turbidity, pollutants and toxins to the receiving water body, flood storage, and water sheeting reduction in urban environments.*
Regulation of Physical Environment	*Ecosystem services assist in the regulation of the physical environment by providing water, air and soil quality improvements through a variety of environmental processes such as the atmospheric release of nitrogen gases, break down of wastes and organics, and the reduction of nitrate deposition into water bodies.*
Regulation of Biotic Environment	*These services create better lifecycle maintenance and habitat protection, pest and disease control, reduction of invasive species, and habitat diversity strengthening.*

Capital Focused Ecosystem Service Categorization

The **Common International Classification** and **Earth Economics Classification** categories of ecosystem services focus less on the monetary benefits that are achieved from the natural environment. Ecosystem services can also be described in more direct values, the processes can be analysed and categorized by interpreting the value in dollars that the service provides to a community or city using various scientific metrics and methodologies. This can take the form of a relatively simple equation that describes a process such as the pounds of nitrogen dioxide captured and stored by an

[8] Pan Parks Foundation. *The Economics of Wilderness.* 2012. Europe.

acre of oak savannah forest habitat over a year or the amount in tons of carbon dioxide sequestered in a densely populated coniferous forest. It can also involve the complex modelling of an entire landscape to understand the values achieved from the surrounding natural environment.

The Public Land Trust assisted the City of Charlotte and Mecklenburg County in North Carolina by conducting a thorough evaluation of the parks and open space division to understand the dollar value of the services provided in the county and city. For example, the city found that the vegetation present at city owned parks and open space contributed to over $19 million dollars in storm water filtration, reduction and storage for the city.[9]

The study also notes that much of the dollar values were discovered because of the benefits that the city and county were able to realize from services that were present in the parks and open space. Cost avoidance manifests itself in many forms but this report described the health benefits from improved air quality, especially in a densely populated and auto-centric city like Charlotte, North Carolina. The report indicates calculations that suggest the city received an annual $3.8 million dollars in cost savings and that citizens received nearly $80 million dollars in health benefits from improved air quality and active recreation opportunities. Figure 2.3 on the following page describes the categories and types of ecosystem services that the Public Land Trust evaluated in dollar amounts for Mecklenburg County and Charlotte, NC.

[9] Harnik, Peter. The Trust for Public Land. The Economic Benefits of The Parks and Recreation System of Mecklenburg County, North Carolina. 2010. Charlotte, North Carolina.

Figure 2.3—The Public Land Trust Ecosystem Services Categories of Benefits for City Parkland in Charlotte, North Carolina[10]

Hedonic Value	*The property value gained from close proximity of land located near parkland, open space or other natural habitats.*
Tourism Value	*Parkland often requires user fees, rentals and other items used to acquire money from tourism that is both internal and external to the area or region.*
Direct Use Value	*The direct use of the parkland is the recreational and actual physical use of the parkland and include a multitude of activities such as: jogging, using play equipment, rowing a canoe, bouldering, riding bikes or simply picnicking. Direct uses are the passive and active recreational activities that people conduct while in a park space.*
Health Value	*Increasing evidence suggests that obesity and physical activity are major health issues in the United States; parks provide citizens with active recreational opportunities for people to exercise while enjoying themselves in an aesthetically pleasing environment. Health Care calculators describing the difference between people who are active and those who are not and can quantify the potential benefits that parks and open space can provide to citizens.*
Community Cohesion Value	*The economic values of social capital are difficult to define and quantify; however, they are certainly recognized benefits from parks that create cohesion and collaboration in a city. Community gardens, park volunteer groups, and trail development groups are all examples of how parks create community cohesion.*
Reducing Cost of Managing Urban Stormwater	*Parks and open space reduce stormwater management costs by capturing precipitation and or slowing its runoff. This is accomplished from dense tree canopy coverage, a variety of vegetation types, age, and coverage and the size of the rain event.*
Air Pollution Removal Value	*Parks and open space with dense vegetation (especially mature trees) are effective at 'scrubbing' the air and removing carbon dioxide, nitrogen dioxide, particulate matter and sulphur dioxide. Air pollution is damaging to buildings, harmful for health and causes respiratory issues in people with medical problems.*

[10] Harnik, Peter. The Trust for Public Land. The Economic Benefits of The Parks and Recreation System of Mecklenburg County, North Carolina. 2010. Charlotte, North Carolina.

Physical and Biological Ecosystem Services

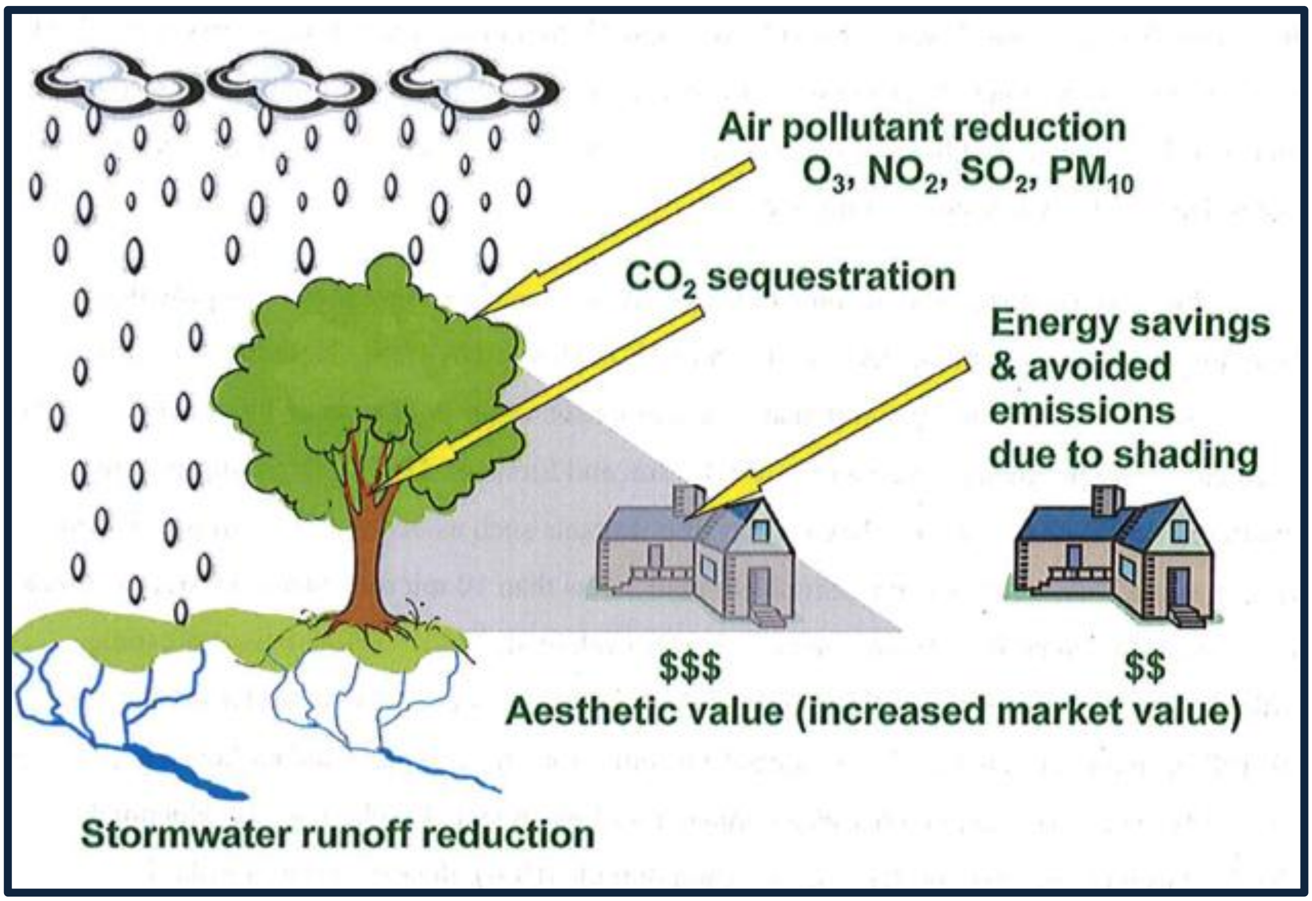
Although many ecosystem services exist, many of the most important and easily visible 'green infrastructures' are the vegetated habitats that are in parks, backyards and along city streets, this are vegetation is comprised of all types, sizes and age. In fact, dense native habitats of such as coniferous stands found on Spencer's Butte provide some of the most important physical and biological ecosystem services. For example, ecosystem services literature suggests that large, mature and native trees provide unique benefits to an urban ecological landscape, by providing shade, carbon sequestration, air cleansing, storm water reduction, and ground water cleansing over large areas and spans of time.[11]

Physical and biological ecosystem services can be thought of in a very similar fashion that traditional stormwater infrastructure opeates. The purpose of urban drainage is primarily to convey urban runoff and snowmelt from an urban area without causing flooding damage to the properties within the city. The 'grey' infrastructure transports the stormwater to a receiving water body usually without treatment. 'Green" infrastructure operates in a similar manner but also has the capability to produce a more hydrologically and ecologically functioning landscape. It makes the structural and natural

[11] American Planning Association. *How Cities use Parks for: Green Infrastructure*. 2003. Chicago, Illinois.

drainage infrastructure more complimentary and far more resilient to extreme meterological events than the current paradigm of the *pipe to daylight* philosophy of grey infrastructure alone. Surface stormwater management that is provided in parks and open spaces is less costly than traditional stormwater infrastucture and has many more positive externalities such as the aesthetic pleasing nature of the infrastucuture.[12] Figure 2.4 describes the 'green' infrastructure aspect of ecosystem services and their useful contribution to the drinking water quality of urban environments. Green infrastructure provides a variety of benefits beyond the ability to facilitate cleaner storm water, it also can provide air pollution reduction, heat and solar insolation reduction, aesthetic benefits and carbon sequestration.

Figure 2.4—Image Describing the Typical Ecosystem Serices Contributed by 'Green Infrastructure'



[13]

[12] Novotony, V. *Water Centric Sustainabile Communities: Planning, Retrofitting, and Building the Next Urban Environment.* 2010. Hoboken, New Jersey.

[13] Don Phillips Ph.D, *Assessment of Ecosystem Services Provided by Urban Trees: Public Lands Within the Urban Growth Boundary of Corvallis, Oregon.* Environmental Protection Agency, Western Ecology Division. 2011.

Air Quality Promotion

Air pollution can have a damaging effect on the buildings of cities, health of the residents, and natural habitats of the surrounding area. Epidemiological research over the past two decades has determined that there is a direct relationship between poor air quality and a decline in overall human health.[14] One of the most integral ecosystem services is the ability of the trees, bushes, shrubs and other vegetation to capture and remove pollutants from the air. Vegetation removes gaseous air pollution primarily by the uptake via leaf stomata, though some gases are removed by the plant surface. Once inside the leaf, gases diffuse into intercellular spaces and may be absorbed by intercepting airborne particles, the plant absorbs some particles or tree and some remain on the plant surface.[15] Pollutants travel through the plants by translocation via the xylem and phloem. Chemical pollutants are absorbed by the leaves and are translocated to the root areas where they can be broken down by microbes in the soil, pollutants in the soil and roots ban be broken down and translocated to the leaves where they are released into the atmosphere. Figure 2.5 on the following page describes a flow diagram of the process in which vegetation promotes the air quality.

Vegetation and trees and also reduce building energy use which has a corollary effect with power usage during warmer months and by blocking winds and insulating buildings during cooler months. If building energy use is lower consequently the use of energy from traditional power production is lower, this leads to improved air quality, lower nitrogen oxide emissions and ground level air pollutants.[16]

Trees an Ecosystem Service Powerhouse for Air Quality

Trees are vital components of the natural cleansing and scrubbing processes that remove, store and reduce air pollutants found in an area. Trees minimize air pollutants such as ozone, nitrogen dioxide, sulphur dioxide and particulate matter less than 10 microns in size—this pollution reduction is achieved by the uptake of gases and interception of airborne particles.[17]

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[14] DSS Management Consultants, Inc. *Health Care Utilization Due to Air Pollution: A Recommended Plan of Action*. Ontario Medical Association). http://www.oma.org/phealth/HCUAPb.htm (1999).

[15] Smith, H. *Air Pollution and Forests.* Springger—Velag. New York. 618. (1990).

[16] Verrengia, J.B. *Hybrid poplar trees clean polluted soil: Researchers still studying phytoremediation*. Houston Chronicle. Houston, TX. (1998).

[17] Nowak, DJ. Crane, D.E. *Air Pollution Removal by Urban Trees and Shrubs in The United States.* Urban Forestry & Urban Greening. 4: 115-123. (2006).

Trees that are healthy and growing store and sequester carbon dioxide within the roots, bark and foliage of the vegetation—this is of growing importance because of the rise in carbon dioxide levels in the earth's atmosphere, a primary contributor to climate change. A study of Atlanta's regional air quality found that trees in the Atlanta metropolitan area removed 19 million pounds of air pollutants annually for annual savings valued at approximately $47 million dollars.[18]

Mature trees are particularly effective at reducing pollution when compared to smaller trees, a large mature coniferous tree can remove 60-70 times more pollution than a small tree. Mature trees provide real and measurable benefits to the air quality of a surrounding region and can be particularly effective in or around the urban—rural interface. According to a report conducted by the College of Forest Resources at The University of Washington, mature trees can reduce 120-240 pounds of particulate matter from the air a year.[19] Particulate matter is a common non-attainment air pollutant monitored by Lane Regional Air Protection Agency (LRAPA). Large coniferous trees in the region can help to remove particulate matter especially particulate matter 5 microns or less, (PM 5.0).

Canopy cover is especially important for the removal of air pollution as it captures small particles in the foliage; it also facilitates the absorption of air pollution such as carbon monoxide, sulphur dioxide, and ozone. A study by University of California group found that vegetation is extremely effective at removing small particulate matter and molecules from the air.

The study indicated that:[20]

- In a test of coniferous vegetation and its ability to remove small particulate matter PM 2.5 microns or less that coverage of 2 meters of vegetation can remove 75% of the matter in ambient wind conditions of less than 3 meters an hour.
- At low to medium wind velocities (1-3 meters/per hour) coniferous vegetation has a strong capacity to capture fine and very fine particulate matter including, heavy metals, dust fugitives and greases.

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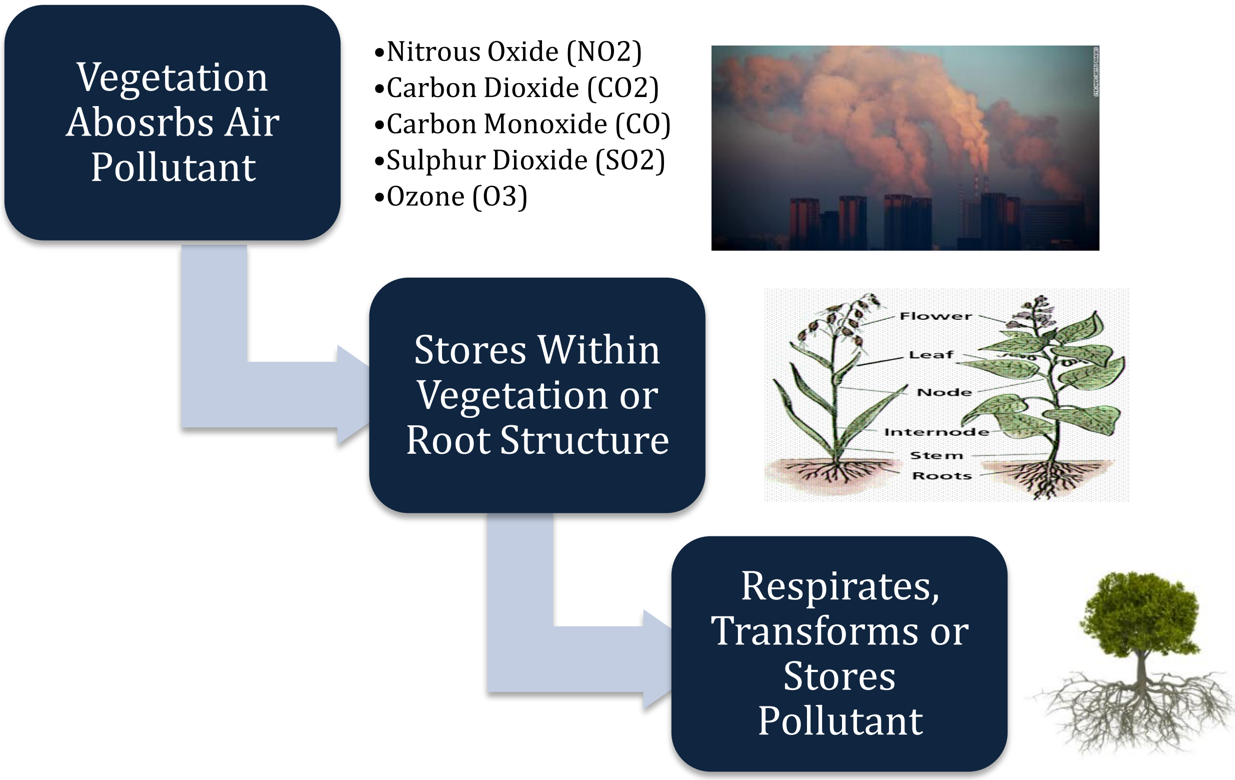
[18] American Forests. *Urban Ecosystem Analysis Atlanta Metro Area: Calculating the Value of Nature.* (2001).

[19] University of Washington. *Urban Forest Values: Economic Benefits of Trees in Cities.* College of Forest Resources. (1998).

[20] Cahill, T. *How Does Vegetation Affect Air Pollution Removal.* Workshop on the Role of Vegetation in the Mitigation of Air Quality Impacts from Traffic Emissions. (2010).

Figure 2.5—Process of Air Quality Ecosystem Service



Carbon Sequestration

"Carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities. In 2012, CO_2 accounted for about 82% of all U.S. greenhouse gas emissions from human activities. Carbon dioxide is naturally present in the atmosphere as part of the Earth's carbon cycle (the natural circulation of carbon among the atmosphere, oceans, soil, plants, and animals). Human activities are altering the carbon cycle—both by adding more CO_2 to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO_2 from the atmosphere. While CO_2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution."[21]

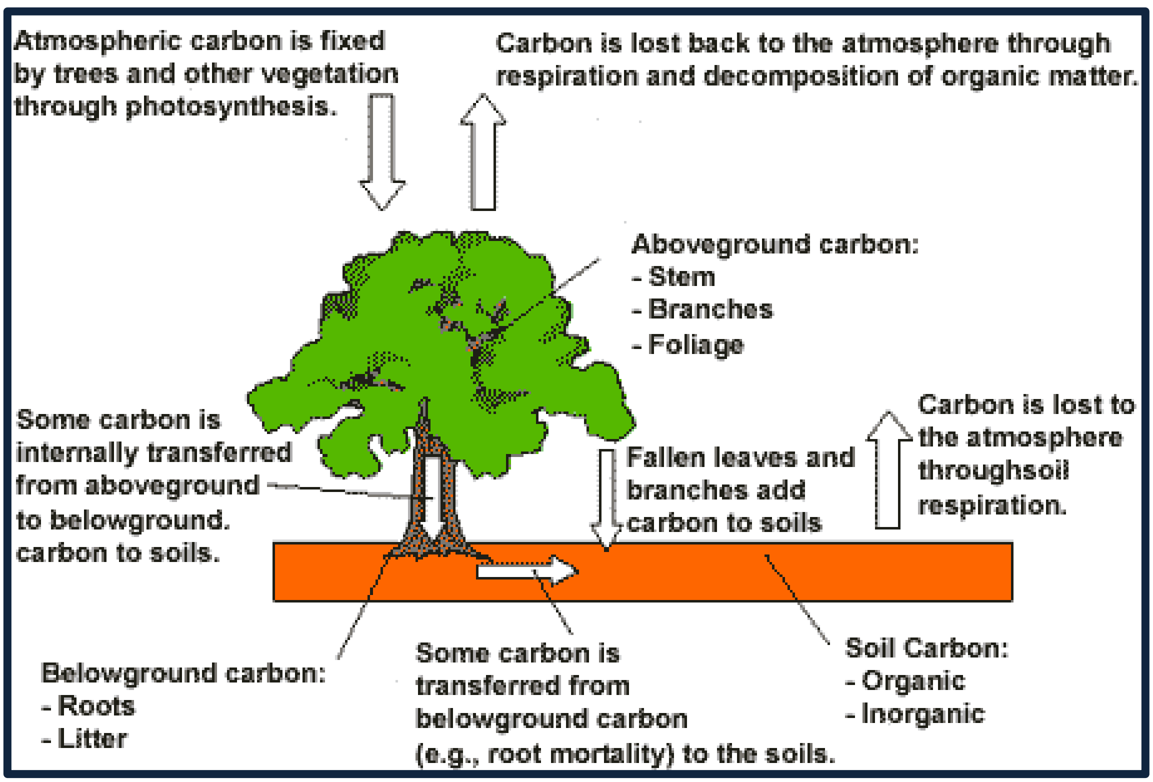
Photosynthesis is the photochemical process by which plants convert sunlight to create nutrients into sugars and carbohydrates, which they use to grow and survive. Carbon dioxide is one of the essential components used in the process of photosynthesis where carbon dioxide is essentially converted into plant biomass—where it is 'stored' in its leaves, roots, and other plant tissues until it dies. Soils also

[21] National Research Council. *Advancing the Science of Climate Change.* National Acadademy Press, Washington D.C. (2010).

absorb carbon from the roots and microbes use the carbon dioxide as part of the process for food and to build the root system of the plants biomass.[22]

Carbon sequestration is an important ecosystem service provided by vegetated habitats, especially during an era where the effects of climate change are increasingly visible and destructive. Carbon dioxide is approaching the 400 parts per/million (ppm) level as of 2014. A potentially disastrous mark for the levels of carbon dioxide in the ambient atmosphere. Forests store substantial amounts of carbon and help to alleviate and reduce the impact of carbon dioxide by storing the carbon and slowly releasing it over time. Figure 2.6 below describes the process in which carbon is stored in vegetation.

Figure 2.6—Process of Air Quality Ecosystem Service



[22] Gorte W. R. *Carbon Sequestration in Forests.* Congressional Research Service. (2009).

Chapter 3: Spencer's Butte Ridgeline Habitat

Ecological and Natural History

This section describes the natural and ecological history of Spencer's Butte, details the habitats at the park and summarizes a report conducted on Spencer's Butte by an ecological organization in Eugene.

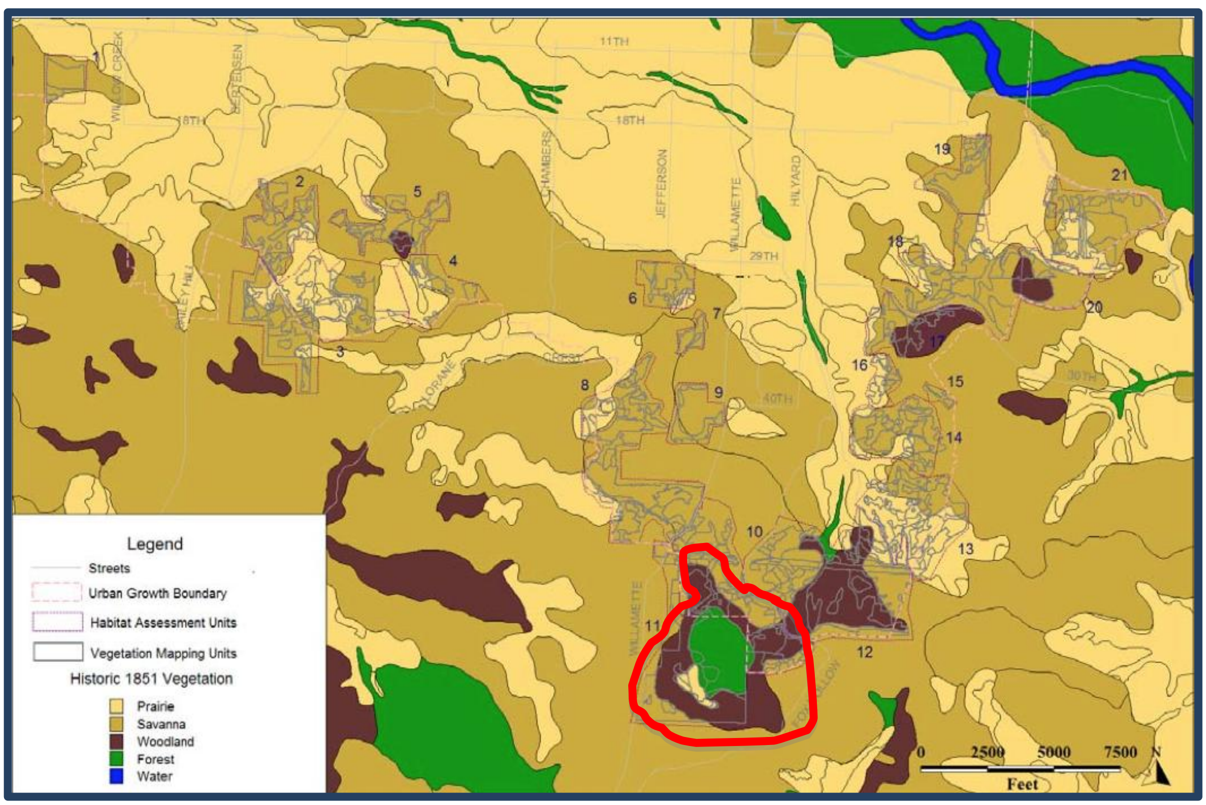
Some controversy exists over the naming of Spencer's Butte; however, some history scholars recognize the following story as one of the more likely scenarios for naming the highest Butte located in the vicinity of present day Eugene, Oregon. "Spencer's Butte was named in the early 1800's for an adventurous member of the Hudson Bay Company. This young Englishman, named Spencer had been traveling west as a fur trapper. Spencer left his group to hike the unnamed Butte and was apparently scalped by Indians"[23]

The Kalapuya Native American people inhabited the Willamette Valley prior to the migration of Euro-American families and individuals into the area during the early to mid-1800s. The land management

[23] Environmental Studies Service Learning Program. *Spencer Butte Recreational Impact Study.* University of Oregon. (2002).

techniques that the Kalapuya used to maintain an abundant food supply in the region are a major factor in the development of the ecological environment in the Willamette Valley. To continue providing an abundant food supply, the Kalapuya frequently used burning of the surrounding area to minimize the encroachment of trees and shrubs into the prairie and grassland habitats that provided the Kalapuya with their food supply. As a result, plant and habitats adapted to the regular, low-heat and low-intensity fire management agricultural practices which lead to a dominant savannah / prairie type habitat on the lower elevations of the Willamette Valley floor.[24] This created the mix of savannah, prairie, mixed forest, conifer forest and deciduous forest habitats that are found on Spencer's Butte; however, as time has passed mixed forest has encroached on the savannah and grassland habitats and has led to a significant change in the ecological landscape over the past 100+ years. The following map (Figure 3.1) depicts an inventory of ~ 1851 vegetation found on the Southern Ridgeline Habitats of Eugene, Oregon. As displayed in the map, historic vegetation at Spencer's Butte was dominated by Woodland and Forest with a small portion of the habitat comprised of prairie and savannah.

Figure 3.1—Historic Vegetation Map of South Ridgeline Habitat Areas—Eugene Oregon Circa 1851[25]



[24] Salix Associates. *ISSSU—South Ridgeline Habitat Study*. Eugene, Oregon. (2007).

[25] Oregon Biodiversity Information Center. ORNHIC Plant Data Layers. 2001.

As settlers migrated to the area and began to occupy land surrounding the South Ridgeline Habitats, the landscape of the area began to follow a different course of ecological management. The new ecological management morphed the local landscape away from oak savannah and prairie to an agricultural and mixed forest landscape. Much of the prairie and savannah habitats were modified for farming, which included agricultural crops, cattle husbandry, trapping, hunting and forestry. The open land of the ridgeline areas was well adapted for raising crops of various types—the prairie and savannah habitats contained especially productive soils, received a steady and reliable source of precipitation and were easily tilled because of the burning practices conducted by the Kalapuya. Settlers raised onions, sweet corn, boysenberries, raspberries, hay, oats, alfalfa, wheat and tobacco. Settlers also trapped, hunted, conducted forestry and raised livestock near and within Spencer's Butte and other South Ridgeline Habitats near Eugene.

Current Ecological Habitat of Spencer's Butte

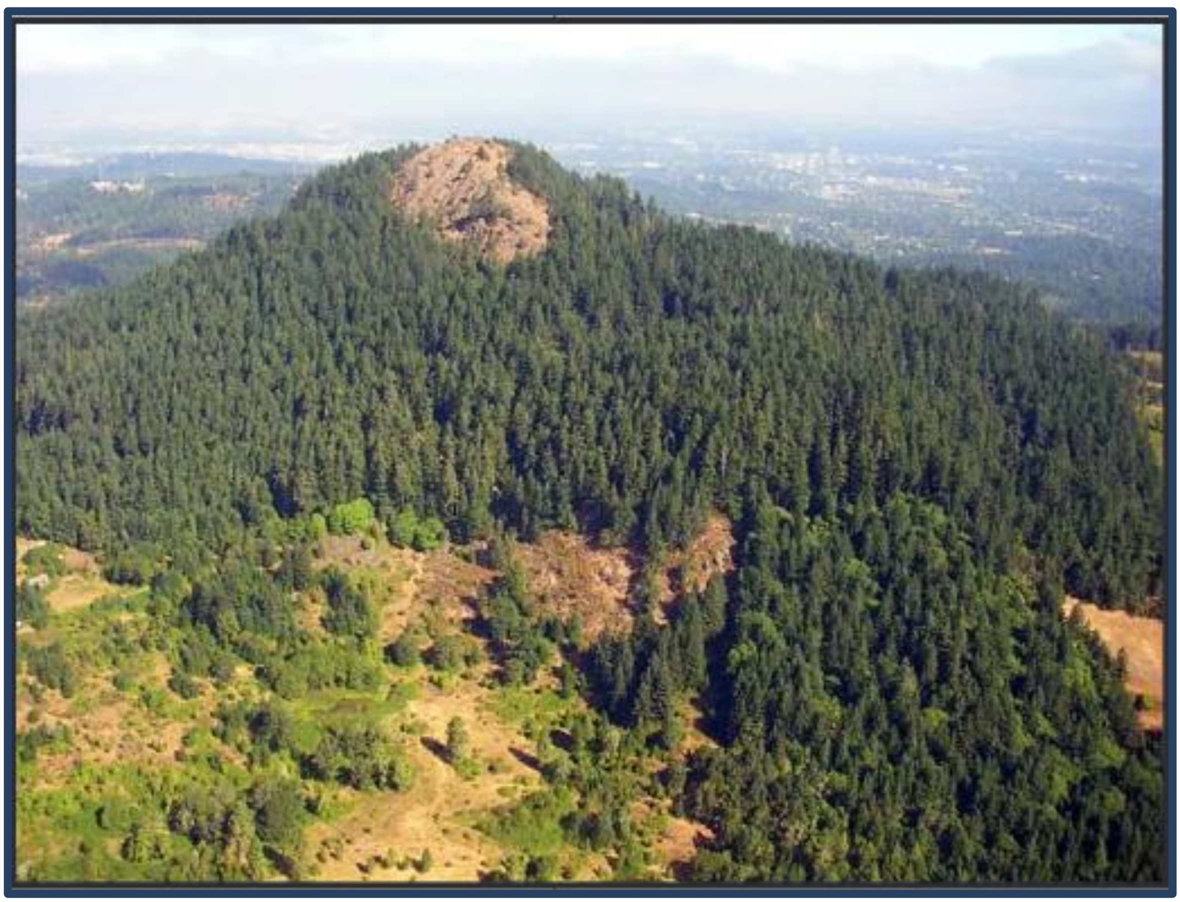


Photo Source: City of Eugene Parks and Open Space Department

Spencer's Butte Park is a unique and diverse city owned park and open space area with a variety of vegetation types. According to data sourced from the City of Eugene, Spencer's Butte has an approximate area of 338 acres. It is described as a unique and diverse micro-ecosystem; the habitat area contains a mixture of open and disturbed prairie, savannah remnants, and native woody vegetation.[26] Much of the ridgeline area is predominantly covered by a combination of Oregon White Oak and Ponderosa Pine, "The forest stand on the North-East slope contains some of the oldest and largest Diameter at Breast-Height (DBH) Douglas Fir and Grand Fir tree stands in the Eugene area". Figure 3.2 is an example of this type of forest.

Figure 3.2—Douglas Fir Stands[27]

[26] Salix Associates. *ISSSU—South Ridgeline Habitat Study*. Eugene, Oregon. (2007).

[27] Humboldt University. *Douglas Fir Tree Stands on the Border of California and Oregon.* 2010.

Diagram 3.3 below describes the most common vegetation types and species present in the Skinner's Butte open space area. The South Ridgeline Areas also feeds into a variety of watersheds most of which ultimately feed the Willamette River. The headwaters of Willow Creek, Amazon Creek, Russel Creek, Spencer Creek and Wild Hog Creek all originate from the Southern Ridgeline Habitat area.28

Diagram 3.3—Common Vegetation Types Found on South Ridge Line Habitats[29]

Category of Vegetation	Common Native Species
Trees	Douglas fir, Bigleaf maple, Oregon White Oak
Shrubs	Snowberry, Poison Oak, Oceanspray, Tall Oregon Grape
Forbs	Sword Fern, Trailing Blackberry, Oregon Iris, Bracken Fern
Grasses	Blue Wildrye, Columbia Brome

The majority of the northern section is described as disturbed prairie and contains small habitats for several uncommon to rare species. A narrow portion of the ridgeline trail access area is dominated by stands of Oregon White Oak, Ponderosa Pine and Douglas firs. Most of the parkland is populated by forest with the exception of the rocky outcropping located at the top of the butte. The forest stand located on the northeast slope of the Butte contains some of the largest Douglas fir and grand fir in the Southern Ridgeline Habitat Area in Eugene. This suggests an ability to intercept, slowdown and absorb large levels of water, which in turn creates improved soil retention and reduced turbidity, nutrient deposition and water sheeting into the receiving Amazon watershed area. The abundance of large and mature mixed coniferous forests significantly contributes to the ability of Spencer's Butte habitat to reduce air pollution—especially ozone, nitrogen dioxide and sulphur dioxide. Figure 3.4 depicts the mixed coniferous forest habitat that is commonly found on Spencer's Butte.

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[28] Ridgeline Area Planning Partnership. *Ridgeline Area Open Space Vision and Action Plan Background and Context. (*2006).

[29] Salix Associates. *ISSSU—South Ridgeline Habitat Study*. Eugene, Oregon. 2007

Figure 3.4—Recreational Trail on Spencer's Butte with Native Trees and Herbaceous Understory Vegetation[30]

Figure 3.5—Oregon White Oak at Spencer's Butte[31]

[30] Oregon Biodiversity Information Center. ORNHIC Plant Data Layers. (2001).

[31] Spencers' Butte Wildland Preservation. *Oregon White Oak.* spencerbuttewildlands@gmail.com. 2014

Ecological Functions of Spencer's Butte and Surrounding South Ridge Habitat Sites

Despite the change of ecological habitats from a predominantly oak savannah and grassland habitat in the region, including Spencer's Butte, Southern Ridgeline Habitat Sites still provide a suite of unique ecosystem services. The following bulleted list is described in a report by Salix Associates [32]– a natural resources consulting firm – that delineates the South Ridgeline Habitat Study Ecological functions. The bolded functions found in this list are biophysical ecosystem processes that are correlated with ecological functions found on Spencer's Butte and the surrounding area:

- Provide habitat for native plants, animals, fungi and microbial life
- Provide habitat for rare species
- Provide connectivity for native species movement and gene flow
- Contribute to maintaining surface water quality and quantity by providing infiltration and slow release into surface streams—especially the Amazon Watershed area
- Contribute to slope stabilization and erosion control
- **Contribute to air quality by taking in carbon dioxide and releasing oxygen, and reducing airborne pollution such as carbon dioxide, sulphur dioxide and ozone**
- Provide special habitat features needed by certain plant, wildlife and fungi species, including: rocky areas, snags and logs, wetlands, large trees, etc.

[32] Salix Associates. *ISSSU—South Ridgeline Habitat Study*. Eugene, Oregon. 2007

Chapter 4: Air Quality


[33]

Overview

This section provides an overview of the Clean Air Act, air pollutants, and the governmental organizations that monitor and enforce air quality standards nationally and regionally in Lane County. A scan of the air quality standards and pollutants provides context for the methodology of this research.

Clean Air Act

The United States Congress under the direction of the Environmental Protection Agency (EPA) established the clean air act. The main purpose to reduce hazardous or toxic chemicals, reduce smog and acid rain, reduce damage to the ozone layer and lessen regional haze found in parks and other recreational areas.

[33] Montana—Ponderosa Pine Tree Stand. *Montana Photo Gallery.* History.com. 2014

"Congress established much of the basic structure of the Clean Air Act in 1970, and made major revisions in 1977 and 1990. Dense, visible smog in many of the nation's cities and industrial centers helped to prompt passage of the 1970 legislation at the height of the national environmental movement. The subsequent revisions were designed to improve its effectiveness and to target newly recognized air pollution problems such as acid rain and damage to the stratospheric ozone layer."[34] Of the six pollutants, particle pollution and ground-level ozone are the most widespread health threats.

The Clean Air Act requires the EPA to set and periodically revise National Ambient Air Quality Standards (NAAQS)—common and widespread air pollutants also known as criteria pollutants that are found all over the United States. The fifty states must collaborate and develop plans with the EPA to monitor and mitigate or reduce the criteria level pollutants so that the local jurisdictions meet the national expectations for air quality. If a region is over the threshold level of a particular air pollutant that region or municipality will be in 'not-attainment' and must take measures to reduce the air pollutant. Ultimately, if 'non-attainment' lasts over a long period of time the federal government will withhold highways funds or induct large fines on the city or region found in non-attainments.

Air Pollutants[35]

The following material is directly sourced from the Environmental Protection Agency and describes five of the six commonly measured air quality pollutants. These pollutants are used and analysed in the model described in Chapter 6: Findings.

- Particulate Matter
- Ozone
- Sulfur Dioxide
- Carbon Monoxide
- Nitrogen Dioxide

Particulate Matter

Particle pollution, also known as particulate matter (PM), includes the very fine dust, soot, smoke, and droplets that are formed from chemical reactions, and produced when fuels such as coal, wood, or oil

[34] Environmental Protection Agency. *The Clean Air Act in a Nutshell: How it Works.* (2013). http://www.epa.gov/air/caa/pdfs/CAA_Nutshell.pdf

[35] Environmental Protection Agency. *Air Resources Page.* http://www2.epa.gov/learn-issues/air-resources#air-pollution. (2014).

are burned. For example, sulfur dioxide and nitrogen oxide gases from motor vehicles, electric power generation, and industrial facilities react with sunlight and water vapor to form particles. Particles may also come from fireplaces, wood stoves, unpaved roads, crushing and grinding operations, and may be blown into the air by the wind.

- The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in diameter pose the greatest problems, because they can get deep into your lungs, and some may even get into your bloodstream.
- Exposure to such particles can affect both your lungs and your heart. Small particles of concern include "inhalable coarse particles" (such as those found near roadways and dusty industries), which are larger than 2.5 micrometers and smaller than 10 micrometers in diameter; and "fine particles" (such as those found in smoke and haze), which are 2.5 micrometers in diameter and smaller.

Ozone

Ground-level ozone is a primary component of smog. Ground-level ozone can cause human health problems and damage forests and agricultural crops. Repeated exposure to ozone can make people more susceptible to respiratory infections and lung inflammation. It also can aggravate pre-existing respiratory diseases, such as asthma. Children are at risk from ozone pollution because they are outside, playing and exercising, during the summer days when ozone levels are highest. They also can be more susceptible because their lungs are still developing. People with asthma and even active healthy adults, such as construction workers, can experience a reduction in lung function and an increase in respiratory symptoms (chest pain and coughing) when exposed to low levels of ozone during periods of moderate exertion.

- Ozone in the air we breathe can harm our health—typically on hot, sunny days when ozone can reach unhealthy levels. Even relatively low levels of ozone can cause health effects. People with lung disease, children, older adults, and people who are active outdoors may be particularly sensitive to ozone.
- Children are at greatest risk from exposure to ozone because their lungs are still developing and they are more likely to be active outdoors when ozone levels are high, which increases their exposure. Children are also more likely than adults to have asthma.

Sulphur Dioxide

Sulfur dioxide (SO2) is one of a group of highly reactive gasses known as "oxides of sulfur." The largest sources of SO2 emissions are from fossil fuel combustion at power plants (73%) and other industrial facilities (20%). Smaller sources of SO2 emissions include industrial processes such as extracting metal from ore, and the burning of high sulfur containing fuels by locomotives, large ships, and non-road equipment. SO2 is linked with a number of adverse effects on the respiratory system.

EPA first set standards for SO2 in 1971. EPA set a 24-hour primary standard at 140 ppb and an annual average standard at 30 ppb (to protect health). EPA also set a 3-hour average secondary standard at 500 ppb (to protect the public welfare). In 1996, EPA reviewed the SO2 NAAQS and chose not to revise the standards.

Breathing ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Ground level ozone also can reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue.

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless gas emitted from combustion processes. Nationally and, particularly in urban areas, the majority of CO emissions to ambient air come from mobile sources. CO can cause harmful health effects by reducing oxygen delivery to the body's organs (like the heart and brain) and tissues. At extremely high levels, CO can cause death.

EPA first set air quality standards for CO in 1971. For protection of both public health and welfare, EPA set a 8-hour primary standard at 9 parts per million (ppm) and a 1-hour primary standard at 35 ppm. In a review of the standards completed in 1985, EPA revoked the secondary standards (for public welfare) due to a lack of evidence of adverse effects on public welfare at or near ambient concentrations.

Nitrogen Dioxide

Nitrogen dioxide (NO2) is one of a group of highly reactive gasses known as "oxides of nitrogen," or "nitrogen oxides (NOx)." Other nitrogen oxides include nitrous acid and nitric acid. EPA's National Ambient Air Quality Standard uses NO2 as the indicator for the larger group of nitrogen oxides. NO2 forms quickly from emissions from cars, trucks and buses, power plants, and off-road equipment. In addition to contributing to the formation of ground-level ozone, and fine particle pollution, NO2 is linked with a number of adverse effects on the respiratory system.

EPA first set standards for NO2 in 1971, setting both a primary standard (to protect health) and a secondary standard (to protect the public welfare) at 0.053 parts per million (53 ppb), averaged annually. The Agency has reviewed the standards twice since that time, but chose not to revise the annual standards at the conclusion of each review. In January 2010, EPA established an additional primary standard at 100 ppb, averaged over one hour. Together the primary standards protect public health, including the health of sensitive populations - people with asthma, children, and the elderly. No area of the country has been found to be out of compliance with the current NO2 standards.

Lane Regional Air Protection Agency (LRAPA)

The Lane Regional Air Protection Agency was created in 1968 to achieve and maintain clean air in Lane County, Oregon in a manner consistent with local priorities and goals. With the support of its member entities, which include Lane County and the cities of Eugene, Springfield, Cottage Grove and Oakridge, LRAPA carries out its mission to protect and enhance air quality through a combination of regulatory and non-regulatory programs and activities.

The agency plays an active role in community development and planning, and works collectively with other local governments and community groups to help achieve federal Clean Air Act goals and objectives**. Mission:** To protect public health, community well-being and the environment as a leader and advocate for the improvement and maintenance of air quality in Lane County.[36]

Air Quality Data and Trends

Air quality data and trends are monitored and recored by LRAPA which provides annual reports that summarize trends in air quality for the agency's are of responsibility. Overall, the air quality in Eugene is generally good and does not typically exceed measured air pollutants frequently during the year. This coincides with an area that has done large amounts of resoration and protection of habitats within the area and an interest in Vehicle Miles Traveled (VMT) reduction measures. The long-term trends suggest improvement in air quality over time for Lane County. Figure 4.1—4.3[37] on the following pages display the decrease in ozone, and particulate matter 2.5 and 10 microns over time. Carbon Monoxide data is no longer collected because of a long attainment period in Lane County.

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[36] Lane Regional Air Protection Agency. *About us: LRAPA Website.* (2014). http://www.lrapa.org/about_LRAPA/index.php

[37] [37] Lane Regional Air Protection Agency. *Annual Report—2013 .* www.lrapa.org. (2014).

Figure 4.1—Particulate Matter 1985-2013 (10 microns)

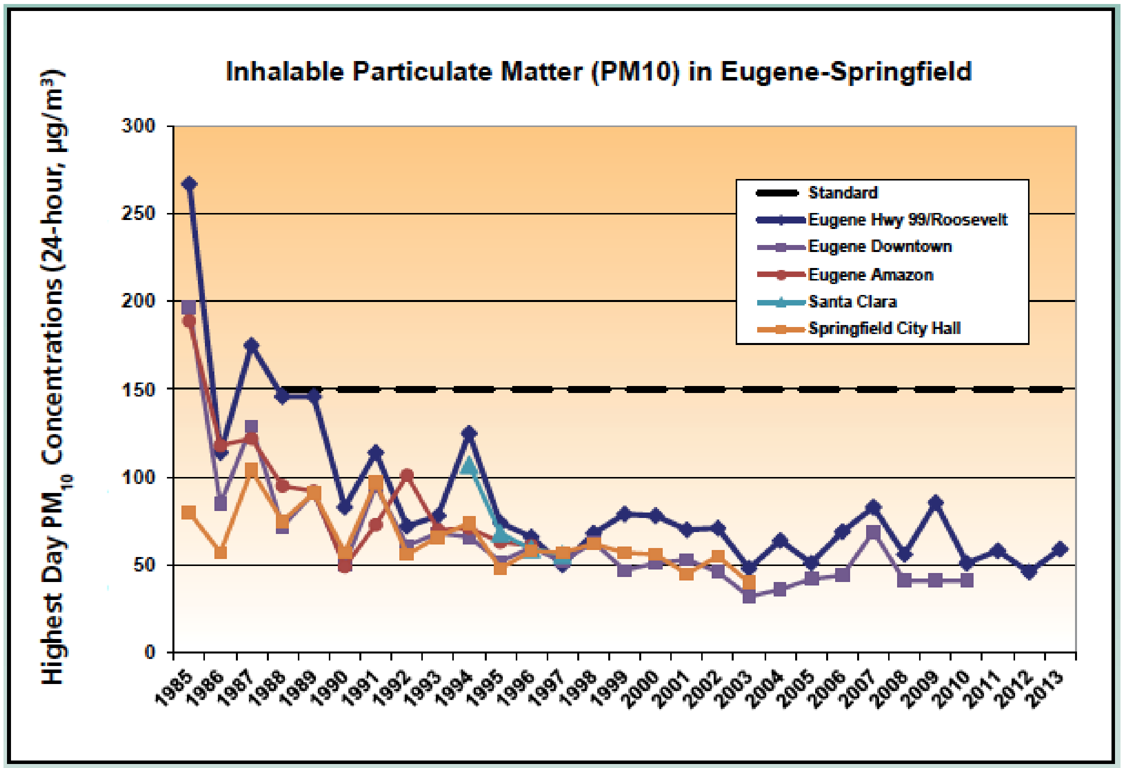


Figure 4.2—Particulate Matter Trends 1985-2013 (2.5 microns)

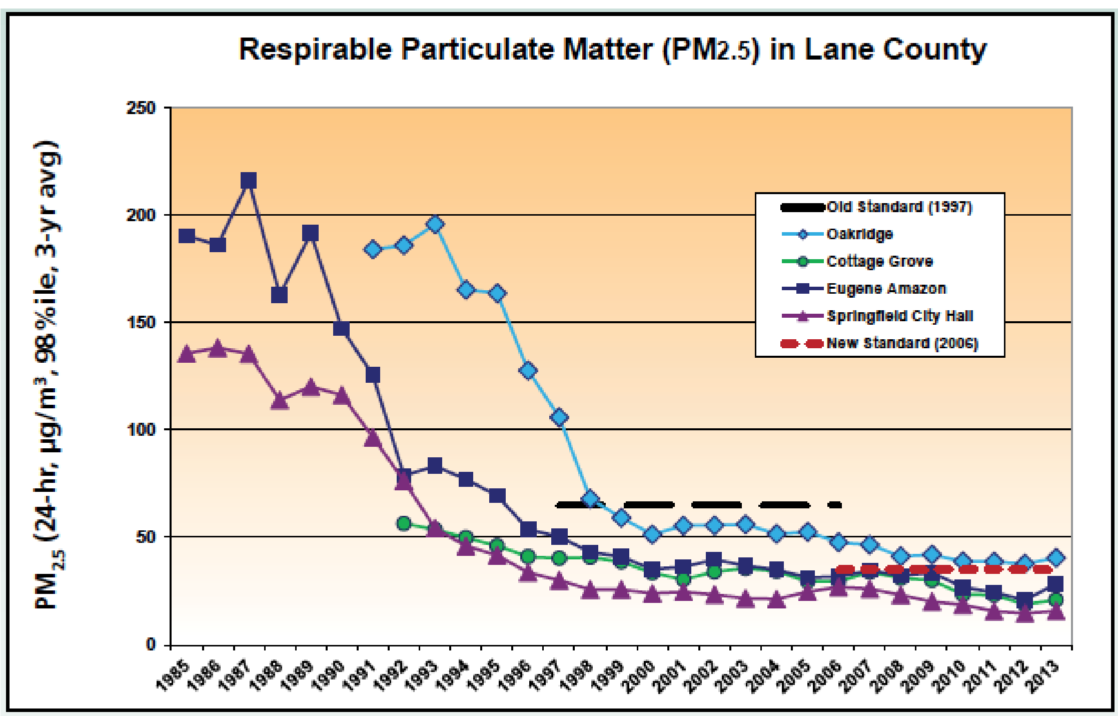
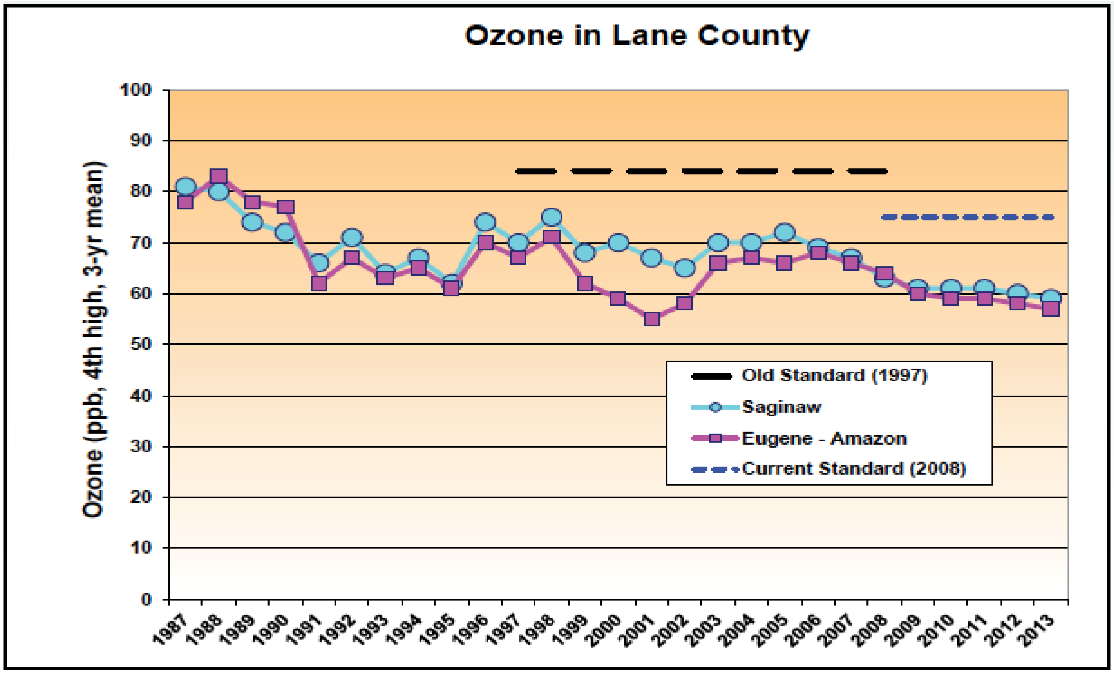


Figure 4.3—Ozone Trends 1987-2014



Chapter 5: Methodology for Evaluating Ecosystem Services[38]

This chapter describes the methodology used for the valuation of ecosystem services at Spencer's Butte Park, the chapter includes the data sources and a description of the model and its limitations.

Data Sources

The data found in this report are derived from a variety of sources including primary and secondary data sources. The following bulleted list describes the major areas from which data, information and evidence for the report are derived:

- White Papers
- Professional Reports
- Dissertations of Research
- Municipal and Agency Reports and Documents
- City of Eugene GIS and spatial data
- City of Eugene quantitative and qualitative data about South Ridge Line habitats
- Methodological analysis and tools from governments, private sector consulting firms and non-profit organizations
- National Land Use Cover and Canopy Data

The City of Eugene provided key data to perform ecosystems services evaluation work. This along with other reports conducted by consulting firms and the University of Oregon provide the research with a unique set of secondary data, all of which allows for the opportunity to access information that would otherwise be difficult to attain. The Eugene Parks and Open Space Department provided data about the park system, open space, and habitat types found on city owned property. The City also provided more detailed quantitative data about characteristics such as the amount of acreage by habitat type or the presence and amount of 'Heritage Trees' in a particular area.

Qualitative data such as the health of trees or observational notes about water and air quality, and anecdotal information about how ecosystems services work in the Eugene park system was also found from other secondary sources. The majority of this material was produced from University of Oregon

[38] Green Renaissance. Facebook Image. 2014.

reports and research projects or from private consulting firms in the area. Research and conclusions from were also collected and analysed to determine established and effective methodologies for ecosystem evaluation—specifically attributing quantitative information to attributes of habitat such as short-tons of carbon dioxide cleansed by a 330 acre by Oak Savannah and mixed conifer forest on a ridgeline habitat. This information is compiled with the intent to provide a range of dollar values accrued through cost avoidance to or protection of unique habitats.

iTree Suite Vue—A Methodological Tool for Air Quality and Carbon Sequestration

"I-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and community forestry analysis and benefits assessment tools. The i-Tree tools help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the environmental services that trees provide and the structure of the urban forest Developed by USDA Forest Service and numerous co-operators, i-Tree is in the public domain and can be downloaded for free.[39]" The software utilizes a series of information from the Multi-Resolution Land Characteristics (MRLC), a consortium group of federal agencies who coordinate and generate consistent and relevant land cover information at the national scale for a wide variety of environmental, land management, and modelling applications.

Model Inputs

The tool uses National Land Use Cover Data as model inputs such as satellite imagery, orthography, LiDAR images, regional air quality data and other regional air quality variables to develop an analysis. Much of the data is derived from a variety of governmental agencies that conduct mapping and imagery analysis. The iTree Vue Model evaluates the **following land cover criteria in the bulleted list below:**

- Canopy coverage in acreage and percentage
- Coverage by vegetation type (shrub, trees, herbaceous)
- Impervious layer coverage
- Coverage by land use type
- State and regional air pollution averages for six common pollutants

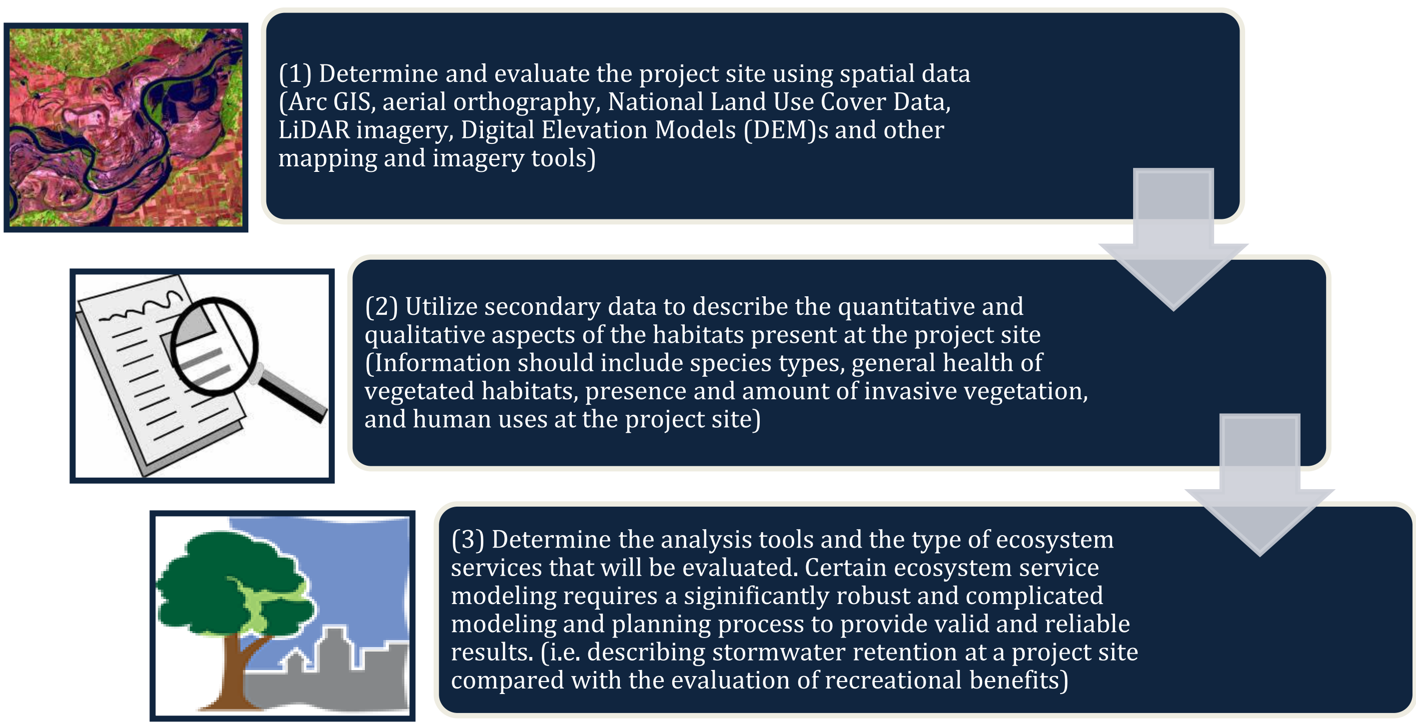
[39] United States Forest Service. I-Tree: About. http://www.itreetools.org/about.php (2014).

- A spatial location or landscape area
- Trade-off equations that describe how ecosystem services are evaluated in dollar amounts; for example, if 383 acres of coniferous forest were removed what would be the impact on average to humans who would have previously received air quality benefits from the forest

iTrees—Vue; Results from Spencer's Butte Project Area

The i-Tree Tools help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the structure of community trees and the environmental services that trees provide.[40] The process diagram below describes the basic approach to utilizing iTrees software for ecosystem service evaluation.

Figure 5.1—Process Diagram for iTrees Ecosystem Service Software Model



The results from iTrees Vue are not only reliable but provide a good 'ball-park' estimate of the capital valuation of ecosystem services. The model is relatively precise when describing the canopy cover percentage, herbaceous cover percentage, and impervious surface values at The Spencer's Butte project site. This software has the potential to be utilized in a scenario where an analysis seeks to view a larger landscape scale, including the Urban Growth Boundary (UGB) of Eugene, Oregon.

[40] iTrees Website. *Brief Description of iTrees Ecosystem Modeling Software. (2014). www.itrees.org.*

Spencer's Butte—National Land Coverage Data Image Area: 388.7 Acres

The following bulleted list describes the types of land cover by type and delineates the criteria that are used to determine how the various types of land cover are displayed and represented in the iTrees modelling suite software. The Spencer's Butte project site contains all of the items on the list but is primarily comprised of mixed forest and evergreen forest. Figure 5.2 on the following page details the types of land cover, acreage and percentage of total project site.

- **Developed, Open Space** - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- **Deciduous Forest -** Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
- **Evergreen Forest -** Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
- **Mixed Forest -** Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
- **Shrub/Scrub -** Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
- **Grassland/Herbaceous -** Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Figure 5.2 iTree—Vue Spencer's Butte Land Use Coverage and Canopy Cover by Acreage

Land Cover Attribute	Acreage	% of Acreage
Tree Canopy	256.1	65.9%
Impervious Cover	1.1	0.3%
Developed	9.3	2.4%
Forest (all)	343.2	88.3%
Wetlands	0	0.0%
Agriculture	0	0.0%
Miscellaneous	36.3	9.3%
Water	0	0.0%
Total Land Use Cover on and surrounding Spencer's Butte	388.7	100.0%

Limitations of The Model

The most significant issue with the iTree modeling software are some of the equations and assumptions that are used to quantify air quality ecosystem services into dollar values. An accomplished ecological economist highlighted the methodological limitations and inadequacies of this research.

The main limitations with iTree Vue Model are:

- Lack of precision with variables such as local air pollution levels in a city
- Lack of precision when describing the amount of carbon already present in a given tree stand and how much ambient carbon dioxide is present in a project site
- Models that provide capital valuation dollar amounts are based on esoteric equations that describe 'trade-offs' rather than empirical valuations—for example, health benefits from air quality are quantified across the United States or the Globe and are based on the premise of removing the trees and what impact that would have on air quality
- Tree canopy coverage is usually 10% underestimated due to imaging resolution
- Model frequently underestimates and can also overestimate the extent of ecosystem services providing air quality benefits in the project area

Chapter 6: Findings

[41]

This section describes the findings from the literature review, iTrees modeling software and other anecdotal information discovered during the research process. The material below describes the salient points learned from the research and how those findings inform the conclusions and recommendations sections following this chapter.

Finding (1)—Ecosystems Modelling Requires a Unique Set of Professional Expertise

- Ecosystems services requires a unique skill set combination of ecological awareness, planning and landscape architecture skills, economic valuation expertise, and an adept computer science understanding.
- An ecosystem service modelling in dollar values is likely to only produce a numerical range rather than an exact dollar amount. The use of modelling software entails limitations that are not easily defendable or explainable without an intimate understanding of the processes, variables, and mathematical functions used to develop the range of values.
- A consultant, municipality or NPO is likely to find that the spatial variables and attributes of an area will vary considerably. This leads to complexities found within appropriately modelling an area, it can be exceedingly difficult to accurately and effectively evaluate ecological functions especially on the site to small landscape spatial scale.

[41] Willamalane Parks and Recreation District. *Live It: Current Planning Projects.* 2012.

Finding (2)—Spencer's Butte has a Dense Canopy Layer Suggesting a Strong Potential for Air Quality Benefits

- According to iTrees—Vue Spencer's Butte has a large tree canopy cover layer, this suggests the potential for air quality improvements as well as the ability to intercept particulate matter, and rainfall from storm events.
- A large proportion of the total canopy cover area, approximately 245 acres or 63.2% of the project site is coniferous vegetation. Within the 245 acres of evergreen forest on the butte, 81.2% of the trees provide a dense tree canopy layer. Figure 6.1 displays the statistics for the various types of cover; the figure describes percent of each type of cover compared to total acreage and percent of land use cover that can be defined as 'tree canopy'.

Figure—6.1 Land Cover Attributes for Spencer's Butte

Land Cover Attribute	Acreage	% of Acreage	% Tree Canopy
Forest (all)	343.2	88.3	72.4
Deciduous	11.8	3	63.8
Coniferous (evergreen)	245.7	63.2	81.2
Mixed	50.9	13.1	73.5
Shrub / Scrub	34.7	8.9	11.3
Total Land Cover	386.2	100	74.6

Finding (3)—Carbon Dioxide Sequestration Abilities of Spencer's Butte

- The ability to store and sequester carbon at Spencer's Butte is a strong ecosystem service that is provided to the region and highlights the importance of large and relatively mature tree stands of a variety of vegetation types. According to iTrees—Vue approximately 1,256 short tons of carbon dioxide are stored and sequestered on Spencer's Butte, which equates to approximately $24,000 in ecological benefits. Figures 6.2 and 6.3 describe the yearly and year-to-date carbon sequestration with associated dollar values for the carbon storage.
- Benefits are evaluated using methodologies that measure the trade-offs in energy generation. For example, the social and environmental externalities of constructing a 100 MW solar installation versus a 100 MW coal fired power plant. These equations were extrapolated for use on this model.
- **Note: on Carbon Dioxide Sequestering Methodology**: Monetary values associated with urban tree carbon storage and sequestration were based on the 2001-2010 projected marginal social cost of carbon dioxide emissions, $22.8/t C (Fankhauser 1994). Pollution removal dollar value estimates were calculated using 1994 national median externality values used in

energy decision making (Murray et al. 1994, Ottinger et al. 1990). The 1994 values were adjusted to 2007 dollars based on the producer price index (U.S. Dept. of Labor 2008).

Figure—6.2 Approximation of Short Tons of Carbon Dioxide Sequestered Yearly at Spencer's Butte

Short Tons Carbon Dioxide Stored Each Year	Short Tons CO2	Dollar Value of Storage
Developed / Open Space	36.7	$713.60
Forested All Classes	1,219.20	$23,682.70
Miscellaneous	0.4	$8.30
Entire Area	1,256.30	$24,404.60

Figure—6.3 Approximation of Short Tons of Carbon Dioxide Sequestered Over the Past 30 Years at Spencer's Butte

Total Carbon Sequestered (Approximately 30 years)	Short Tons CO2	Dollar Value of Storage
Developed / Open Space	1,114.4	$21,646.90
Forested All Classes	36,980.90	$718,373.90
Miscellaneous	____	____
Entire Area	38,095.30	$740,271.60

Finding (4)—Air Pollution Removal and Abatement of Spencer's Butte

- The findings from the modelling software indicate a strong preponderance for the ability to mitigate and reduce a variety of air pollutants—especially Ozone and Particulate Matter less than microns (PM10). Because many residents in the Eugene area still use woodfire places to heat their homes in the winter, the ability of trees at Spencer's Butte to capture and reduce particulate matter is an especially important ability of the butte. Particulate matter is also generated from dust fugitives, automobile travel, industrial processes (especially wood manufacturing) and dry conditions that promote the distribution of minute particles. An EPA report of non-attainment counties for air quality found that in 2008 approximately 75% of (PM 2.5) was generated from residential wood burning, 22% was a result of industrial processes and the remainder generated from road salting and transportation. These results indicate the importance of a thick canopy layer that has the ability to 'scrub' and remove particulate matter from the air with a dense leaf to area ration.
- Figure 6.3 is a whole encompassing air pollution removal diagram that indicates the ability of the project site—388 acres to remove almost 15,700 pounds of airborne pollutants from the

air on a yearly basis. This figure equates to approximately $63,000 dollars in ecosystem service capital valuation.

- Figures 6.4—6.8 describe the amount of air pollution removed by Spencer's Butte vegetated habitats each chart describes the total pounds removed per year with an associated capital value placed on that ability to remove air pollution. Air pollutants removed are the following:
    - Nitrogen Dioxide—NO2
    - Ozone—O3
    - Sulphur Dioxide—SO2
    - Particulate Matter < 10 Microns—PM (10.0 <)

Figure—6.4 Total Air Pollutants Removed Yearly From Spencer's Butte

Total Pollutants Removed Yearly	Total Pounds	Dollar Value of Storage
Developed / Open Space	473	$1,868.70
Forested All Classes	15,700.80	$62,012.00
Miscellaneous	5.4	$21.60
Entire Area	16,179.20	$63,902.30

Figure—6.5 Total Nitrogen Dioxide Removed Yearly From Spencer's Butte

Total Nitrogen Dioxide Removed Yearly	Pounds NO2	Dollar Value of Storage
Developed / Open Space	29.6	$21.50
Forested All Classes	982.30	$712.40
Miscellaneous	____	____
Entire Area	1,012.30	$734.10

Figure—6.6 Total Ozone Removed Yearly From Spencer's Butte

Total Ozone Removed Yearly	Pounds O3	Dollar Value of Storage
Developed / Open Space	182.0	$433.60
Forested All Classes	6,039.30	$14,389.00
Miscellaneous	2.1	5
Entire Area	6,233.40	$14,827.60

Figure—6.7 Total Sulphur Dioxide Removed Yearly From Spencer's Butte

Total Sulphur Dioxide Removed Yearly	Pounds SO2	Dollar Value of Storage
Developed / Open Space	54.5	$68.20
Forested All Classes	1,810.10	$2,262.70
Miscellaneous	____	____
Entire Area	1,865.20	$2,331.70

Figure—6.8 Particulate Matter Less Than 10 Microns Removed Yearly From Spencer's Butte

Total Particulate Matter (PM10) or Less Removed Yearly	Pounds (PM10 <)	Dollar Value of Storage
Developed / Open Space	122.1	$416.20
Forested All Classes	4,051.10	$13,810.60
Miscellaneous	____	____
Entire Area	4,174.60	$14,231.60

Chapter 7: Conclusions and Recommendations

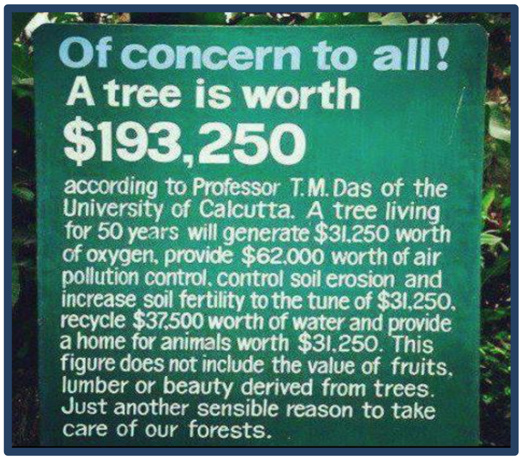
This chapter outlines the conclusions and recommendations derived from the findings of the research. These recommendations are meant to be used as a launching point for further research, a possible guide for the City of Eugene Parks and Open space Department to use as a tool for discussing ecosystem services with the community, and as a general overall conclusion and 'wrap-up' of the research. Each recommendation contains a variety of more specific action items that are described in bullet points under the main header. The specific action items are more specific guides for accomplishing the recommendation or conclusion.

Recommendation (1)—Educate and Inform

The importance of information and education about ecosystem services is that is begins to create an understanding within the community about ecosystem services and how they contribute to local and regional air quality. A community that is well informed about the processes and importance of ecosystem services will likely be more willing to contribute to the protection, mitigation and restoration of habitats that provide ecological services.

- Develop a suite of educational and informative materials that can easily convey the importance of parks and open space for cost avoidance as a result of EPA non-attainment procedures.
- Instead of the popular mailing method, which can be costly investing in signage at parks with proven ecosystem services can help to convey the importance of the habitats ability to provide services to humans and the surrounding environment.
- Convey the importance of air quality standards and the ability of a robust and healthy park system with mature and tree stands to promote the air quality standards in the region. Describe the importance of maintain attainment to regional air quality standards and the implications if that attainment is not made.
- Employ and develop signage can describe ecosystem service benefits, including: air pollution removal, storm water reduction and cleansing, soil retention qualities or the value of the recreational attributes of the park system. This type of signage can be attractive durable and easily visible and conveyed if placed in appropriate high-traffic areas.
- Use information kiosks that are attractive with imagery than describes the importance of 'heritage trees' and mature coniferous tree stands that convey a large proportion of ecosystem services especially in the form of air quality benefits including pollutant reduction and carbon sequestration.

Figure—7.1 Image of Signage Discussing the Value of Trees and Ecosystem Services[42]



Recommendation (2)—Build Data Sources and Databases

A robust data set is useful for almost any endeavour in ecology, planning or landscape architecture. A dataset that details the location, source and relevance of ecosystem services and the modelling software that evaluates those services is a useful tool for a municipal government. A robust database can significantly reduce the time and effort required to locate and determine the appropriateness of the data for use in ecosystem service valuation.

- Build and improve upon sets of data and reports such as work conducted by Earth Economics, Salix & Associates, The University of Oregon and other groups and consulting firms that increase the understanding and value of ecosystem services in the area.
- Compile a database that is easily accessible by the public, academics, government officials and agencies to develop an increased collaborative effort to detail and describe ecosystem services in the region. The database could prove extremely useful to groups or individuals who are interested in conducting analysis of the surrounding area—these reports can be compiled into the database which would be particularly useful to the Public Works Department and Parks and Open Space Department of Eugene and surrounding municipalities.
- Utilize reports and data to build an argument for increased funding for the restoration, protection, and mitigation of important ecological habitats.
- Create maps and diagrams that detail the highest value sources of ecological benefits that are easily conveyed to the public, professionals and city officials

[42] Green Rennaissance. Facebook Image. 2014. Original Source Unknown.

Recommendation (3)—Restore, Improve and Mitigate

An intact and healthy ecological habitat has the strongest ability to perform ecosystem services. The maintenance and stewardship of vegetated habitat areas will ensure that the services provided will remain strong and relatively constant. Additionally, a large expense in time and capital is often required to restore degraded habitats to a level that allows the habitat to contribute effectively to ecosystem services. The more habitats are protected, improved and mitigated from further damage the more healthy the ecosystem is and the greater the capacity of the area to provideecosystem services.

- Ensure the protection, restoration and improvement of natural areas in the Eugene Parks and Open space area, especially unique habitats such as the South Ridgeline Habitats, Alton Baker Park, Delta Ponds and other densely vegetated area that provide high value ecological services to the community at large.
- Use recreation studies conducted by The University of Oregon and update the inventory to understand the usage patterns of individuals and groups whom use and recreate in the area. Update recreational usage patterns can be utilized to tailor a program that seeks to protect high value / usage ecological areas.
- Work with Soil and Water Conservation Districts, Watershed Groups, Trail maintenance organizations, volunteer groups and city organizations to conduct restoration and mitigation activities on city owned park and open space areas.
- Place special consideration to the restoration of damaged habitats and the mitigation of unique and relatively undamaged areas that provide unique ecological benefits to the area. Focus could be applied to the unique 'bald' and rocky outcrop areas on the South Ridgeline Habitat, these areas contain unique habitats that are rapidly disappearing in the region.
- Work with arborists, ecologists and landscape architects to further inventory, record and understand the habitats found within Eugene Parks and Open space land. Conduct restoration, habitat mitigation and improvement of existing habitats especially those that contribute high value ecological services to the surround region.
- Develop a stronger understanding of the various vegetation types, especially mature 'heritage trees' and the relative contribution to ecosystem services that are provided by various species, ages and types of trees and vegetation.
- Remove invasives wherever possible, especially invasive herbaceous life that will likely threaten or endanger large and mature tree stands found on Spencer's Butte.
- Develop studies and reports that evaluate the effects of climate change on ecosystems in the South Ridgeline area and other parks. Special considerations should be taken to evaluate and develop measures to protect and maintain the most unique habitat such as The Mariposa Habitat found on Spencer's Butte.

Recommendation (4)—Collaborate with City Agencies

Collaboration with city agencies is a crucial aspect of ecological planning and requires significant effort and participation from the respective city agencies. The advantage to inter-agency cooperation is that efforts can be combined—labor and capital can be pooled in a collaborative effort to work on a variety of aspects related to ecosystem services. For example, LRAPA and The City of Eugene would both benefit from collaborative efforts to explain the importance of the densely vegetated habitats in the city and how these areas contribute to local and regional air quality.

- Work with the City of Eugene Public Works Department, Lane Regional Air Protection Agency and Eugene Water and Electric Board (EWEB) to build the case for ecosystem services that contribute to various air quality standards monitored by The Lane Regional Air Protection Agency.
- Consider appropriating larger amounts of dollars to the park system to protect and maintain habitats that provide high value ecological functions.
- Use data from reports and studies that display the economic benefits that are seen in terms of cost avoidance from EPA non attainment fines for air quality standards, cost avoidance to stormwater infrastructure, soil retention and erosion prevention, and vegetation that supports pollination and in turn the large agricultural community in the surrounding area.

Recommendation (5)—Develop Recreational Habit Understanding

Eugene is an active community that values the ability to recreate passively and actively in the parks and open space in the city. An active populace is generally a healthier one; however, a report by University Students evaluating the recreational habits of park users at Spencer's Butte indicated widespread habitat destruction and degradation at Spencer's Butte. Park users often travel off paths, brings dogs off-leash, litter and damage rare and sensitive ecological amenities. Informing the recreational users about the importance of the habitats on Spencer's Butte and how certain actions such as staying on paths can contribute to the longevity and health of the environment at the park would be useful for protecting this unique area.

- Incorporate information from 2002 Recreational Habit Study conducted by University of Oregon team to mitigate damage to rare and unique ridgeline habitat and vegetation. Damage caused by human and canine intervention can exacerbate erosion, expose roots of mature 'heritage trees', and compact soils—which reduces the ability of the area to allow for rainwater infiltration that causes water sheeting and increased alluvial erosion. Damage to trees root structures can cause a degradation in the ability of mature tree stands to reduce and mitigate airborne pollutants, especially particulate matter less than 10.0.
- Mitigation efforts should include dedicated and signed paths as well as signage that illustrates the damage caused by dogs off-leash and humans making their own paths at the park. Damage

Recommendation (6)—Build Source of Planning and Ecological Documents That Create Action

Research and informative documents are important, but the creation of action-oriented reports, plans and guidelines helps organizations and municipalities to manifest their values into reality. A go-to source of documents that provide guidelines and suggestions for improving the ecosystem services for a community can help to realize that goal.

- Collaborate and utilize existing planning documents and action plans that seek to restore, protect and mitigate the removal and destruction of existing habitat found on Spencer's Butte Open Space and Natural Area.
- Utilize Ridgeline Area Open Space and Natural Area Vision and Action Plan and follow guidelines and suggestions for the improvement of ecological areas on the ridgeline including Spencer's Butte.

Appendix A: iTrees Vue Methodology Advantages and Limitations Discussion

Overview

To accurately assess ecosystem services of an urban forest, users need to collect data in the field on their resource to produce information related to species composition, tree sizes and tree health. This type of information is critical not only for urban forest assessments, but also urban forest stewardship. The i-Tree program is designed to get users in the field to assess their urban forest.

i-Tree Vue is a new program that provides coarse estimates of tree cover and some urban forest ecosystem services without requiring the user to collect field data. As this program does not require field data collection, the estimates can only be considered very coarse approximations with some significant limitations to the data and estimates. Users are encouraged to collect local field data to provide better estimates.

i-Tree Vue has several advantages, but also has some serious limitations that need to be understood by the user:

Advantages:

- Can provide coarse estimates of tree cover and air pollution removal and carbon storage and annual carbon removal (sequestration) for anywhere in the United States
- No field data are required
- Needed data can be derived from available data sets
- User can visualize variations in urban tree cover and ecosystem services for their area
- Allows users to simulate effects of changes in tree cover on ecosystem services
- Ability to generate output datasets for use in GIS

Disadvantages and Limitations:

Generalized Estimates – The basic approach to i-Tree Vue is to use spatial tree cover maps developed by the National Land Cover Database (NLCD) (http://www.mrlc.gov/) and apply average ecosystem service values per unit of canopy cover to estimate services of the local area. This generalized approach using national or state averages has significant limitations at the local scale.

NLCD Tree Cover Estimates – NLCD provides tree cover estimates within 30 meter pixels for entire lower 48 states. This national database provides important information on our national tree resources, but has limitations, particularly at the local scale. Tree cover estimates from the NLCD cover maps are believed to be underestimating tree cover in by an average of about 10 percent (Greenfield et al., 2009). However, the degree of underestimation varies across the nation. Thus, the tree cover and consequently ecosystem service estimates in cities and towns are likely conservative, but the degree of underestimation in specific locations is unknown. Better estimates of tree cover can be obtain through aerial photo interpretation or the development of higher resolution tree cover maps using LIDAR technology (e.g., http://www.nrs.fs.fed.us/urban/utc/).

Air pollution Removal Estimates – to more accurately estimate pollution removal in a city, local pollution and weather data are needed, as well as local estimates of the leaf area index (depth of canopy) and canopy cover. As local data are unknown in i-Tree Vue (except for the estimate of tree cover), i-Tree Vue uses state average estimates of annual pollution removal per square meter of tree cover (g/m2/yr) to estimate local pollution removal assuming a local leaf area index of 6 (i.e., 6 m2 of leaves (one-sided) per m2 of canopy cover). As pollution concentrations, weather and urban forest leaf area indices can vary significantly at the local level, i-Tree Vue estimates are coarse at best. The closer your area conditions are to the state average and a leaf area index of 6, the closer the i-Tree Vue estimate will be for your area. How far your conditions vary from these conditions are unknown. Better estimates can be obtained by collecting local field data and using i-Tree Eco. More information on air pollution removal methods are given below.

Carbon Storage and Sequestration Estimates – to more accurately estimate carbon storage (amount of carbon currently in trees) and annual carbon sequestration (amount of carbon removed in one year) in a city, local environmental conditions (e.g., tree competition, length of growing season) and tree density, species, and diameter distribution information are required. As local tree data are unknown in i-Tree Vue (except for the estimate of tree cover), i-Tree Vue uses national average estimates to approximate local carbon effects. Carbon sequestration and storage values are estimated from tree cover (m2) multiplied by average carbon storage (9.1 kg C/m2), and sequestration (0.3 kg C/m2) density values derived from several U.S. communities (e.g., Nowak and Crane 2002, Nowak and Greenfield, 2008). As tree population and environmental variables can vary significantly at the local level, i-Tree Vue estimates are coarse at best. The closer your area conditions are to the group average, the closer the i-Tree Vue estimate will be for your area. How much your conditions vary from these conditions are unknown. Better estimates can be obtained by collecting local field data and using i-Tree Eco.

Dollar value estimates – monetary estimates of ecosystem services are based on literature estimates of values per ton of pollution or carbon. Monetary values associated with urban tree carbon storage and sequestration were based on the 2001-2010 projected marginal social cost of carbon dioxide emissions, \$22.8/t C (Fankhauser 1994). Pollution removal dollar value estimates were calculated using 1994 national median externality values used in energy decision making (Murray et al. 1994, Ottinger et al. 1990). The 1994 values were adjusted to 2007 dollars based on the producer price index (U.S. Dept. of Labor 2008). These values, in dollars/metric ton (t) are: Nitrogen dioxide (NO2) = \$9,906/t, Particulate matter less than 10 microns (PM10) = \$6,614/t, Sulfur dioxide (SO2) = \$2,425/t, Carbon monoxide (CO) = \$1,407/t. Externality values for ozone (O3) were set to equal the value for NO2. Externality values can be considered the estimated cost of pollution to society that is not accounted for in the market price of the goods or services that produced the pollution.

Air Pollution Removal Methods

Air pollution removal estimates are derived from the Urban Forest Effects (UFORE) model (Nowak and Crane 2000) and 2000 weather and pollution data (National Climatic Data Center 2000, U.S. EPA 2008). The UFORE model was used to integrate hourly pollution and weather data with urban or community tree cover data to estimate annual pollution removal in each state (Nowak and Crane 2000, Nowak et al. 2006).

To estimate pollution by urban trees in each state, state pollutant flux rates (grams of pollution removal per square meter of canopy per year) were derived from a study of national pollution removal by urban trees for the year 1994 (Nowak et al. 2006). As pollution concentrations vary through time, the 1994 flux rates were adjusted to 2000 values based on average regional pollution concentration changes between

- 1994 and 2000 (U.S. EPA 2003). As flux rate = deposition velocity * pollution concentration, the ratio o the pollution concentration between years was used to update the flux rate.
- Arithmetic mean concentration values were used for nitrogen dioxide, particulate matter less than 10 microns, and sulfur dioxide, 2nd Max. 8-hr average for carbon dioxide, and 4th Max. 8-hr average for ozone, to determine the ratio of change between 1994 and 2000 (U.S. EPA 2003). The new 2000 flux rates are multiplied by urban or community tree cover to estimate total pollution removal by trees.

Closing Thoughts on Limitations — Although there are limitations to the estimates, the i-Tree Vue is designed to provide easy first-order estimates of ecosystem services for urban areas. These data can used to view variations in existing cover and services, potential changes in services with changes in tree cover, and provide a stepping stone to provide more accurate estimates of services through i-Tree Eco. Data can be used to illustrate the types and general magnitude of service to aid in advocacy for better management and assessments. These data should not be consider as final or accurate estimates of urban tree cover of environmental services.

Appendix B: List of Ecosystem Service Models and Tools for Valuation

[43]

E.S. Modelling Tool	Open Source or Proprietary Product	Time Required to Conduct Analysis	Scalability
Primary Valuation	Results typically accessible via publication in the peer-reviewed or grey literature	High (1 year or more), unless local studies have been previously completed	Results are properly interpreted as dependent on the scenario
Point Transfer	Varies; databases range from open source to proprietary	Low (less than 1 month; less if there is access to a good valuation database)	Site to landscape scale
Function Transfer	Results typically accessible by means of publication in peer-reviewed or grey literature	Low for previously developed functions, high if developing original functions	Site to landscape scale
Defender's of Wildlife Function Transfer	Publicly available	Low	Site to landscape scale
InVEST	Publicly available, requires extensive knowledge and ownership of ArcGIS	Moderate to high, depending on availability of GIS and ecological data to support modelling	Watershed or landscape scale
ARIES	Public available	High to develop new case studies, low for pre-existing case studies	Watershed or landscape scale
MIMES	Publicly available, requires SIMILE modelling software	High to develop and apply new case studies	Multiple scales
Ecometrix	Proprietary	Approximately 150 hours of consultant's time for field visits, data analysis in regions where tool has not yet been applied	Site scale
EcoAIM	Proprietary, requires contracting with the original	Variable: biodiversity model requires extensive	Watershed or landscape scale

[43] USGS. Ecosystem Services Valuation to Support Decision Making on Public Lands—A Case Study of the San Pedro River Watershed, Arizona. Unite States Department of the Interior. 2012.

	program creators	time with inclusion of preferences, mathematical models, trade-off modelling, decision support system framework, monetization more time consuming	
ES Value	Proprietary, requires contracting with Entrix	Approximately 400+ hours of consultant's time per case study	Landscape to watershed scale
Envision	Publicly Available	California, 1 year, $100,000—150,000 to develop a new case study	Landscape scale
EcoServ	Publicly Available	High to develop new case studies, low for existing case studies	Site to landscape scale
NAIS	Proprietary	Variable depending on stakeholder involvement in developing the study	Watershed or landscape scale
SERVES	Subscription based service run by Earth Economics	Relatively low	Watershed or landscape scale
SolVES	Publicly available, requires ArcGIS	High if primary surveys need to be developed	Watershed or landscape scale

E.S. Modelling Tool	Open Source or Proprietary Product	Time Required to Conduct Analysis	Scalability
UNEP—WCMC Ecosystem Services Toolkit	Publicly Available	Low, depending on involvement of stakeholders in the ES survey process	Multiple scales
ESR	Publicly Available	Low (1 week to 1 month, depending on number of stakeholders involved)	Multiple scales
InFOREST	Low; accessed through online interface	Developed and documented only for Virginia	Site to landscape scale

Appendix C: Ecosystem Services Matrixes

Appendix C.1—Direct Use Value of Ecosystem Services Derived From Spencer's Butte—Eugene, Oregon

City of Eugene Spencer's Butte Park and Open Space Area

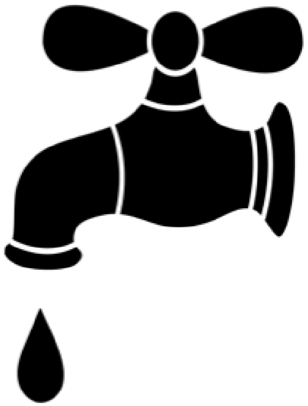
List of Ecosystem Service Vital To Eugene's Healthy Human an Bio-Physical Environment

This matrix describes the initial ecosystem services identified as important and present in the City of Eugene's Spencer's Butte Parkland and Open Space The information in this figure describes the particular ecosystem service and **5 characteristics.** (1) The biophysical process or form of the service, (2) The habitat or vegetation type that typically provides the service, (3) The overall importance of the service to the City of Eugene (4) Where the ecosystem services are taking place (5)The methodologies for measuring the particular ecosystem service

Ecosystem Service	Biophysical Process or Form	Provided by Habitat or Vegetation Type	Overall Importance of Service to Parks and Open Space	Where is this Service Provided?	Methodologies for Measurement
Direct Use Value 	Direct use value often refers to the passive and active recreational uses that are obtained from a city's park system, although some parks charge for a variety of uses the true use of direct value is often underestimated. These uses include direct uses (e.g. kayaking on the canals, biking on the South River Trail or walking at Spencer's Butte Park). Passive uses such as picnicking, relaxing or socializing are also important for the community.	The city of Eugene's Spencer's Butte openspace, trails and parkland provides residents with a variety of recreational opportunities among a mix of landscape and habitat types that are common to the South Hills Ridgeline Area.	**IMPORTANT** Eugene is known regionally and nationally for a strong park system that is valued for its unique assets. Direct use is the most obvious form of ecosystem services but the overall importance of direct use is extremely high especially in an active populous in Eugene that values the ability to actively and passively recreate.	Citywide in all parks, trails, water bodies and open spaces. Soencer's Butte is an especially well used park and openspace area because of its elevation, unique habitats and active recreation opportunities.	Current Direct Use fees and measurements compared to other municipalities with similar demographics and park systems
		m			

Ecosystem Service	Biophysical Process or Form	Provided by Habitat or Vegetation Type	Overall Importance of Service to Parks and Open Space	Where is this Service Provided?	Methodologies for Measurement
Stormwater Treatment and Storage 	Water quality is strongly correlated to the ability of an urban landscape to manage the storm events that effect the built, and natural environment. One of the most important aspects of Spencer's Butte is the ability to store and treat storm water. The stormwater management has large implications for TMDL requirements, especially because the drainage shed flows to an important water body--Amazon Creel. This promotes a much more beneficial water quality for wildlife because of temperature, nutrient and rurbidity reduction of stormwater by natural vegetative processes rather than 'pipe to day light' which tends to produce warmer and more polluted storm water discharge.	Trees, sedges, grassland, gardens and open space in urban areas can protect water quality by substantially reducing the amount of runoff from the more frequent, but less extreme storm events that are responsible for most annual pollutant runoff. Spencer's Butte habitats of open savannah and mature trees allow for infiltration and the treatment of storm water runoff on site. Literature suggests that it can reduce runoff and pollutant loads by 20 -60% found by a Vancouver, WA study of urban vegetation and storm water on similar slope, contour and habitat types. In addition, the combination of all city owned parkland, open space, street trees and other vegetated areas provide a measurable benefit to water quality.	**CRITICAL** Stormwater management for the city of Eugene is managed through EWEB and the MWMC. However, the large amounts of densely vegetated parkland and open space provide considerable amounts of ecosystems service, which literature and scientific evidence suggest are important for stormwater storage and treatment especially during frequent and minor storm events. Stormwater treatment and storage is one of the most discussed and debated ecosystem services because of its increasingly accepted importance as a Best Management Practice for stormwater management.	Parks, open space, street trees and other areas owned by the city that contain vegetation that promotes water quality. Important areas include The South Ridge Line Habitat (including Spencer's Butte), Alton Baker Park and its expanse of riparian habitat and vegetated open space, The Delta Ponds which provide considerable water quality contributions for the city, as well as the variety of urban parks and open space areas that are city owned and maintained. The nature of this service is decentralized as opposed to grey infrastructure.	Stormwater infrastructure cost avoidance calculations TMDL requirement reduction Earth Economics reports and methodologies evaluating stormwater ecosystem services in the Mid-Willamette region and applying those methodologies to the parks and open space regions in the City of Eugene Acre/feet of water stored in certain spatial areas during a .1 .5 and 1 inch rain event Measurements in area of permeable areas that are found in parks, open space and street trees

Appendix C.3—Water Quality Benefit Ecosystem Services Derived From Spencer's Butte—Eugene, Oregon

Ecosystem Service	Biophysical Process or Form	Provided by Habitat or Vegetation Type	Overall Importance of Service to Parks and Open Space	Where is this Service Provided?	Methodologies for Measurement
		m			
Water Quality 	Ecosystem services for water quality can be defined as the reduction and mitigation of pollutants, nutrients, turbidity, toxins, greases, organic material and debris through the filtration, infiltration, percolation, reduction of ground water sheeting and precipitation uptake through the respiratory processes of vegetation. This occurs in the greatest extent within heavily vegetated areas with densely populate mature native trees, grasses, sedges and shrubs.	Riparian habitats, densely planted vegetated parks and open spaces near and along the water sheds and bodies. All vegetation has some water quality benefits but some are much more effective. Native perennial clumping grasses with deep and varying root structures, mature trees with healthy canopies and dense well supported root structures, large swales of dense bushes, sedges and grasses are extremely effective at reducing turbidity and greases.	**CRITICAL** The importance of vegetation in the reduction of pollutant loads into the local and regional watersheds of the area is ***a critical ecosystem resource.*** The recent EWEB project exploring riparian area protection along the McKenzie river lends legitimacy to the vital importance of vegetation as a facilitator of ecosystem services that promote and stabilize water quality on the Willamette and McKenzie Rivers.	Parks, open space, street trees and other areas owned by the city that contain vegetation that promotes water quality. Important areas include The South Ridge Line Habitat (including Spencer's Butte), Alton Baker Park and its expanse of riparian habitat and vegetated open space, The Delta Ponds which provide considerable water quality contributions for the city, as well as the variety of urban parks and open space areas that are city owned and maintained. The nature of this service is decentralized as opposed to grey infrastructure.	Cost Avoidance calculations TMDL Requirements EPA BMPs for evaluating water quality Careful capital valuation of water quality management (e.g. turbidity, fecal coliform, phosphate reduction) using established scientific methodology combined with proven case studies where vegetation has provided ecosystem services that benefited the water quality of the city or region

Appendix C.4—Air Quality Benefit Ecosystem Services Derived From Spencer's Butte—Eugene, Oregon

Ecosystem Service	Biophysical Process or Form	Habitat or Vegetation Type	Overall Importance of Service to Parks and Open Space	Where is this Service Provided?	Methodologies for Measurement
Air Quality 	Equally important to water quality is the the air quality of a region. The air basin in Eugene, monitored by RAPA is routinely indicating higher than normal levels of PM2.5, particulate matter 2.5mm in the Lane county region. The ecosystem services of the parks promote better air quality in the area as it captures, collects, and stabilizes particulate matter that vegetation contacts through wind deposition.	Large trees with dense and healthy canopies. Native coniferous trees are especially effective at reducing particulate matter in the air because of the size, maturity and leaf types of coniferous trees. Bushes, grasses and smaller trees also provide an important role in the promotion of air quality.	**IMPORTANT** Larger than normal volumes of particulate matter can be found in the regional air basin, especially during the winter when people heat homes with wood. The vegetation found in Eugene parks and open space helps to reduce some of the particulate matter in the region, as well as reduce GHGs through respiration of CO2.	Areas within the parks and open space of Eugene that have dense concentrations of mature and healthy coniferous trees, such as Spencer's Butte in the South Hills. Street trees are particularly effective at reducing some of the point source PM and CO2 air pollution from busy city streets.	Contact from Landscape Architect provided a review on the importance of street trees in Eugene with detailed cost figures this will likely be extremely useful for understanding the measurement methodologies for trees and air quality EPA guidelines

Appendix C.5—Soil Quality and Retention Benefit Ecosystem Services Derived From Spencer's Butte—Eugene, Oregon

Ecosystem Service	Biophysical Process or Form	Habitat or Vegetation Type	Overall Importance of Service to Parks and Open Space	Where is this Service Provided?	Methodologies for Measurement
Soil Quality and Retention 	The nature of the steep slopes, and contours found on Spencer's Butte lend to the importance of Soil Quality and Retention; without the presence of a variety of native vegetation much of this soil is lost during rain events through the process of erosion. The process of soil retention and quality begins with undisturbed soils, that are densely planted with a variety of perennial vegetation. The vegetation holds the soils in place during rain events which is key for reducing turbidity and nutrient deposition. Soil quality is maintained through a healthy deposition of decaying organic materials from seasonal vegetation dieoff.	Soil quality is a temporal process--meaning that often the best method for achieving great soil quality is to not touch the quality soils and heavily amend damaged or depleted soils. Soil retention is provided by intact and healthy vegetated habitats, especially densely vegetated habitats with dynamic and mature trees present. Large expanses of native grasses, sedges and shrubs are also extremely effective at soil retention and quality promotion.	**IMPORTANT** Soil quality is vital to the agricultural base of much of Lane county which is dependent on healthy soils for their livelihood. Soil retention is correlated with storm water treatment and storage as well as water quality, the key link between these services is the necessity of dense, native and mature vegetation comprised of a variety of species, age, and canopy structure. The retention of soil is vital to the process because the vegetation is uniquely dependent on the soil as a growth medium.	Specifically within the vegetation of native clumping grasses, sedges, bushes, perennial plants, trees of all varieties and shapes but most important are the presence of healthy mature native trees.	Earth Economics McKenzie River Watershed Capital Valuation Report EWEB Stormwater Reports, before and after Drinking Water Protection Measures GIS Analysis of Contour and Soil Types Habitat reports and studies of soils and vegetation found on Spencer's Butte

Ecosystem Service	Biophysical Process or Form	Habitat or Vegetation Type	Overall Importance of Service to Parks and Open Space	Where is this Service Provided?	Methodologies for Measurement
Health Value 	The health value of ecosystem services can be described as the benefits that humans receive by using park space for active recreation which in turn provides cardiovascular health benefits. Health value can also be derived from ecosystem service end-products and use of the natural environment; drinking water quality is a product of the natural environment and is a tangible commodity that produces health benefits for the residents of Eugene.	Health benefits in the form of exercise, relaxation or the ability to be in natural areas have proven physical and mental health benefits that are important for a society that is struggling with obesity and inactivity. Similar to the stormwater treatment and water quality, the health value benefits produced by clean drinking water are derived from the same the forms of native vegetation and habitats. Plants and habitats especially the park and open space of Spencer's Butte cleanse the water and removes toxins, metals, and reduces the impact of pollutants on the receiving water body.	**CRITICAL** As people have become increasingly more sedentary as a result of many factors, one method for encouraging an active life style is to provide an attractive park system for residents to use such as the large trail network found in city parks in Eugene. Meeting the demands of the EPA and TMDL requirements is an exacting process that necessitates large amount of expensive infrastructure, the ecosystem services that are provided by the green infrastructure in parks is equally effective for drinking water and health benefits.	Parks, open space, street trees and other areas owned by the city that contain vegetation that promotes water quality. Important areas include The South Ridge Line Habitat (including Spencer's Butte), Alton Baker Park and its expanse of riparian habitat and vegetated open space, The Delta Ponds which provide considerable water quality contributions for the city, as well as the variety of urban parks and open space areas that are city owned and maintained. The nature of this service is decentralized as opposed to grey infrastructure.	Drinking water quality case study results of studies describing the benefits of vegetation and riparian areas on the water quality of a city or region. The CDC also has a health benefits calculator which account for the proximity of parks and open space to residential areas as well as size and type of park according to NRPA standards and guidelines. Annecdotal evidence from literature and case studies about the ability of parks, trails and openspace to encourage a more active lifestyle.