REVEALING PROMISING PATHWAYS FOR INCREASING URBAN ECOSYSTEM SERVICES: AN APPROACH COMBINING STAKEHOLDER PRIORITIES WITH ECOSYSTEM SERVICE QUANTIFICATION

by

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THESIS ABSTRACT

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Urban development diminishes the delivery of ecosystem services (ES), defined as benefits from ecological processes and functions critical to human health and well-being. Land-use planners and environmental managers are increasingly familiar with the concept of ES; however, methods for incorporating ES into urban planning are underdeveloped. While previous reports have identified the combination of ES quantification and stakeholder engagement as necessary for increasing the delivery of ES, methods of implementation remain unexplored. To address this disparity, this study combines ES quantification with perspectives from multiple stakeholders to identify specific land cover conversion scenarios that increase the delivery of ES in the Friendly Area Neighborhood of Eugene, Oregon and compares each conversion scenario using an informed weighting system. The result is a method, with potential for use by researchers and public officials, to quantify the delivery of ES, identify stakeholders' ES priorities, and assess the benefits associated with green infrastructure development.

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I. INTRODUCTION

The rapid growth of global urban population and land cover conversion is predicted to continue through the first half of the twenty-first century (Angel, Parent, Civco, Blei, & Potere, 2011; United Nations, 2014). In 2014, over 54% of the global population resided in urban areas, compared to 13% in 1900 (United Nations, 2006, 2014); by 2050, 66% of the world's people will live in cities (United Nations, 2014). At the same time, moderate projections suggest that urban areas will grow from 600,000 km^2 globally in 2000, to 1.9 million km^2 by 2050 (Angel et al., 2011). Although cities cover less than 0.5% of *all* land area (Angel et al., 2005), land use and land cover changes due to urbanization alter hydrological systems, biodiversity, biogeochemical cycling, and climate at local, regional, and global scales (Grimm et al., 2008). Each of these alterations affects one or more ecosystem services (ES), defined as the benefits humans obtain from ecosystems (Gómez-Baggethun et al., 2013; Millennium Ecosystem Assessment, 2005).

The 2005 Millennium Ecosystem Assessment outlined four categories of ES, each encompassing different types of benefits provided by ecosystems. *Provisioning* services consist of the material goods generated by ecosystems (e.g. wood, food, and fresh water). *Regulating* services consist of the benefits derived from ecosystem processes (e.g. air and water purification, climate regulation, and erosion control). *Cultural* services include the aesthetic, spiritual, educational and recreational benefits provided by ecosystems. *Supporting* services consist of the underlying characteristics that allow for continued production of ES (e.g. nutrient and water cycling, habitat provisioning, genetic diversity, and biomass production). All four categories of ES can be provided by green infrastructure, commonly understood as the planned network of vegetated urban areas including parks, natural areas, right-of-way planting strips, private yards, green roofs, and vacant lots (adapted from Derkzen, Marthe L., van Teeffelen, & Verburg, 2017).

Unlike gray infrastructure, designed for the sole purpose of removing water from the urban landscape rapidly, green infrastructure creates opportunities to increase a diversity of urban ecosystem services (UES). For example, trees planted in cities reduce levels of air pollutants harmful to human health, including ozone, carbon monoxide, sulfur dioxide, nitrogen oxides, and particulate matter (Nowak & Dwyer, 2007; Nowak, Hirabayashi, Bodine, & Greenfield, 2014); store atmospheric carbon (Nowak & Dwyer, 2007; Nowak, Greenfield, Hoehn, & Lapoint, 2013); intercept rainfall and reduce stormwater runoff (Xiao & McPherson, 2002); provide shade and air temperature regulation (Akbari, Pomerantz, & Taha, 2001); and increase recreation value (Derkzen, M. L., van Teeffelen, & Verburg, 2015). The above studies demonstrate a strong potential to increase UES through the proactive incorporation of green infrastructure in urban planning and development; however, not all green land cover types provide the same suite of ES.

Lawns are the dominant urban green land cover type throughout urban and suburban areas of the United States, Canada, and Europe and provide multiple ES, as well as environmental concerns. In the United States, over 160,000 km^2 of land is covered by lawn, representing 1.9% of the entire continental U.S. (Milesi et al., 2005). Comparatively, lawn coverage in the United States equates to more than 70% of the irrigated cropland (USDA, 2014) and over 63% of the total urban area in the continental U.S (Ratcliffe, Burd, Holder, & Fields, 2016). While conventional lawns are relatively easy to maintain, water requirements for turfgrass in the U.S. are estimated between 695 and 900 liters of water per person per day (Milesi et al., 2005), and the use of fertilizers, pesticides, and herbicides associated with conventional lawn care has contributed to water quality issues and has proven toxic to fish, birds, and insects (Robbins & Birkenholtz, 2003). While lawns can promote soil carbon storage, fossil-fuel-powered maintenance practices may nullify those benefits (Ignatieva et al., 2015). Lawns do provide regulating services, such as stormwater retention, air purification, and air temperature regulation, as well as spaces for gathering and recreational sports; however, other land cover types, such as woodland, can offer greater air pollutant removal and air temperature regulation, as well as alternatives for outdoor recreation (Derkzen, M. L. et al., 2015; Nowak & Heisler, 2010). The complex environmental and maintenance costs and benefits associated with lawns create a challenge for land use planners in determining what types of green infrastructure would most benefit their cities.

Although both stakeholder perspectives and ES quantification have been identified as critical to effective establishment and management of UES (Haase et al., 2014; TEEB, 2011), urban green space planning currently fails to recognize and operationalize the connection between these two components (Andersson et al., 2014). To investigate ways in which this connection might be realized, this study incorporates multiple stakeholders' perspectives regarding the delivery of UES from public green space with quantification of current UES production by land cover type. The result is a method, with potential for use by researchers and public officials, to identify stakeholders' UES priorities for public green space, quantify the delivery of UES, and assess the benefits associated with future green infrastructure development. The culminating products from this research are a clear ranking of the plausible ES provided by public green space for one neighborhood in Eugene and a comparison of several potential land conversion scenarios designed to increase the delivery of the highest ranked ES.

1.1 Urban Ecosystem Services - Quantification

Over the past 20 years, numerous new methods have emerged to quantify and evaluate the delivery of UES (Haase et al., 2014). Many of these methods use biophysical, empirical, and GIS-based models to quantify to delivery of UES, including air quality (Jim & Chen, 2008; Nowak & Dwyer, 2007), stormwater runoff (Tratalos, Fuller, Warren, Davies, & Gaston, 2007), air temperature regulation (Goldenberg et al., 2017; Wang, Y. & Akbari, 2016), and carbon sequestration (Nowak & Dwyer, 2007; Nowak, Stevens, Sisinni, & Luley, 2002; Townsend-Small & Czimczik, 2010).

In considering the UES provided by particular forms of green infrastructure, it is instructive to evaluate the benefits quantitatively. For example, Beijing's urban forest sequesters approximately 0.2% of the city's annual carbon emissions (Zhao, Tang, & Chen, 2016). Similarly, Chicago's urban forest carbon sequestration is comparable to one week of transportation emissions (Nowak, 1994). If fossil fuel consuming maintenance is factored into the carbon budget for urban forests, there is potential for urban forests to cause net carbon emissions (Nowak et al., 2002). In contrast, urban forests provide significant health-related air quality benefits (Nowak & Dwyer, 2007). In 2010, urban forests in the United States removed 27,000 metric tons of particulate matter under 2.5 microns ($PM_{2.5}$), 523,000 metric tons of ozone (O_3), 68,000 metric tons of nitrogen dioxide (NO_2), and 33,000 metric tons of sulfur dioxide (SO_2) (Nowak et al., 2014). The monetary value of airborne pollutant removal by urban forests in the United States was estimated at $4.7 billion, compared to $2.2 billion for rural forests (Nowak et al., 2014), demonstrating that while urban forests play a negligible role in counteracting anthropogenic carbon emissions, they provide significant benefits in the form of air pollution mitigation.

The development and refinement of modeling and quantification techniques for individual ES has supported research that evaluates ES bundles, or sets of ecosystem services that appear together as characteristics of specific land cover types (Raudsepp-Hearne, Peterson, & Bennett, 2010), provided by urban green space (Derkzen, M. L. et al., 2015). Bundles of UES provided by various land cover types are shown in Table 1. Research that quantifies ES bundles creates a more complete representation of the benefits provided by urban green space. For example, quantifying air purification services of urban forests alone does not allow for an assessment of the tradeoffs, commonly understood as the loss of a certain ES and the concurrent increase of another (Haase, Schwarz, Strohbach, Kroll, & Seppelt, 2012), or the other ES provided by urban forests. Quantifying UES bundles provides a means of comparing ES co-benefits and tradeoffs associated with different land cover types. Derkzen et al. (2015) incorporated a suite of UES quantification methods to differentiate the quantity of UES provided by distinct land cover types (Table 2). Although lawn is the dominant vegetative land cover type in many cities, occupying as much as 75% of a city's urban green space (Ignatieva et al., 2015), and provides soil carbon storage (Qian, Follett, & Kimble, 2010), runoff retention (Ignatieva et al., 2015), and recreation value (Monteiro, 2017), alternative land cover types can offer a greater diversity (Table 1) and quantity (Table 2) of ES. For example, urban forests provide higher rates of air pollution removal, while offering more diverse nesting and foraging opportunities for birds, although lawns and urban forests have similar capacities for erosion prevention and stormwater purification (Derkzen, M. L. et al., 2015; Mexia et al., 2018). Analyzing UES bundles by land cover type creates an opportunity to evaluate existing benefits of public green space and inform future green infrastructure development decisions.

Table 1: Comparing ecosystem service bundles by land cover type.

Land Cover Type	Ecosystem Service Bundle	References
Prairie/Savanna	Habitat for birds/pollinators; native species diversity; air purification; carbon storage; water purification; flood reduction	Vesely and Rosenberg 2010 Cowherd, Grelinger, and Gebhart 2006 Derosier, Hanshue, Wehrly, Farkas, and Nichols 2015
Woodland	Habitat for birds; native species diversity; air purification; carbon storage; flood reduction; water purification; outdoor recreation; climate regulation; soil carbon/nitrogen production	Vesely and Rosenberg 2010 Nowak et al. 2014 Bullock, Hawe, and Little 2014 Derkzen, M. L. et al. 2015 Eastburn, O'Geen, Tate, and Roche 2017
Wetland	Habitat for birds/pollinators; native species diversity; air purification; carbon storage; flood reduction; water purification; natural beauty	Mitsch, Bernal, and Hernandez 2015
Tree (individual)	Air purification; carbon storage; climate regulation; water purification; flood reduction	Derkzen, M. L. et al. 2015 Nowak et al. 2002 Livesley, McPherson, and Calfapietra 2016
Lawn/Herbaceous	Runoff reduction; water purification; air purification; outdoor recreation; climate regulation	Derkzen, M. L. et al. 2015
Swale/Raingardens	Flood reduction; water purification	Walling, Osborne, Lee, and Durham 2014

Table 2: Ecosystem service indicators and supply rates, specified by land cover type

Land Cover (LC) Type+	Description	Air Purification* (g m^{-2} yr^{-1})b	Carbon Storage (kg m^{-2})d	Runoff Retention (L m^{-2})f	Cooling Fraction (LC Fraction: weight)	Recreation* (Index value m^{-2})
Tree	individual tree; LC height >5m	3.97	10.64	8.7 g	1.0	2.15
Woodland	clustered trees; urban forest patch	2.69	15.62	8.7	1.0	2.9
Tall Shrub	LC height (2-5 m)	2.05	7.79	7.3	1.0	2.55
Short Shrub	LC height (0.33-2 m)	2.05	5.61	7.3	1.0	2.55
Lawn/ Herbaceous	lawn/ turf grass (< 0.33m)	0.9	0.17	8	0.5	2.55

Note: Adapted from "Quantifying urban ecosystem services based on high resolution data of urban green space: an assessment for Rotterdam, the Netherlands", by Derkzen, M. L., van Teeffelen, A. J. A., and Verburg, P. H., 2015, Journal of Applied Ecology, 52, p. 1023-4.

+ This study did not distinguish ‘garden’, ‘water’, or ‘other’ land cover types used in Derkzen et al. (2015).

* Dependent on UGS location (air purification rate doubles for UGS within 50-meter road buffer; recreation rate doubles for UGS in municipal parks).

b Air purification expressed in grams of particulate matter with a diameter less than 10 microns (PM_{10}).

d Carbon storage represents cumulative carbon sequestration; not an annual rate

f Runoff retention based on 12 mm storm event.

g Woodland runoff retention value used for all tree cover; Derkzen et al. (2015) expressed runoff retention per tree instead of per m^2 crown area as most individual trees in Rotterdam are planted in constrained areas within paved surfaces; in the Friendly Area Neighborhood, street trees are planted planting strips with grass understory

1.2 Urban Ecosystem Services - Stakeholder Perspectives

Efforts to incorporate green infrastructure into urban land use face significant challenges that vary by city, state, and country. While quantitative analysis of UES presents evidence for benefits of natural, semi-natural, and highly maintained green spaces, it does not address the sociopolitical context that directs future urban land use policy and development.

Public resource policy and management decisions are often made by government agencies without meaningfully incorporating community members into the decision-making process (Menzel & Teng, 2010; Theodori & Kyle, 2013). Although the need for stakeholder involvement has been well-established in environmental management circles since the Word Heritage Convention in 1972 (UNESCO, 2005), its value to ES planning was only brought to the forefront of ES research in the Millennium Ecosystem Service Assessment (2005). Conducting surveys, interviews, and focus groups with stakeholders (i.e. any person, or group, with a vested interest in the outcomes from the management of the space in question) can reveal ES priorities (Castro, A. J. et al., 2011; Castro, Antonio J. et al., 2014; Derkzen, Marthe L. et al., 2017; Jim & Chen, 2008; Madureira, Nunes, Oliveira, Cormier, & Madureira, 2015; Tyrväinen, Mäkinen, & Schipperijn, 2007; Young, 2010), green space design preferences (Derkzen, Marthe L. et al., 2017), and barriers to green infrastructure development (Matthews, Lo, & Byrne, 2015) that are not distinguishable by ES quantification. Incorporating perspectives from publicly elected officials, policy makers, environmental managers, scientists, and affected constituents into ES planning and valuation has accordingly been identified as critical to green infrastructure development (Ahern, Cilliers, & Niemelä, 2014; Andersson et al., 2014; De Groot et al., 2010; Haase et al., 2014; Lovell & Taylor, 2013; Menzel & Teng, 2010).

Many researchers in the field of UES have called for approaches involving stakeholders; however, of the 217 UES studies published from 1973 to 2012 that were reviewed by Haase et al. (2014), only 11% incorporated stakeholders. Most of these studies only consulted one type of stakeholder, which did not accurately represent the diversity of perspectives reliant on UES. According to Haase et al. (2014), incorporating perspectives from multiple stakeholders has been "one of the pervasive challenges in making ecosystem approaches to urban planning operations at the policy and decision making level" (p. 420).

1.3 A New Method for Evaluating Urban Ecosystem Services

Various researchers, seeking to address the challenges to green infrastructure planning, have identified the need to integrate quantitative ES analysis with stakeholder perspectives (Ahern et al., 2014; Matthews et al., 2015; Millennium Ecosystem Assessment, 2005; TEEB, 2011). The provision of UES is limited by both biophysical constraints, including the area available for green space establishment and the type of plants used, and socio-political constraints, which include financial limitations, planning and policy systems, and public support (Matthews et al., 2015). It is conceivable that local governments, planning codes, and resident attitudes obstruct green infrastructure development, although they can also be instrumental in implementing green infrastructure development, even if the increased provision of ES is insignificant (Matthews et al., 2015). Thus, an analysis of the biophysical and sociopolitical context is necessary to reveal the benefits obtainable from green infrastructure development, as well as the feasibility of implementation and maintenance.

To address this problem, this study develops an approach combining stakeholder perspectives with ES quantification and tests it in the Friendly Area Neighborhood of Eugene, Oregon. The primary objectives of this research were to assess the current delivery of ES by land cover type; identify potential land cover conversion alternatives to increase the delivery of stakeholder prioritized ES; and reveal the benefits, barriers, and avenues for overcoming barriers to green infrastructure development. Two stakeholder survey methods were combined with a quantitative evaluation of UES at the neighborhood scale and were used to inform an ES ranking system, creating a set of plausible options for green infrastructure development. These combined analyses create an approach for integrating stakeholders' UES priorities with UES quantification by land cover type, revealing the most advantageous pathways for increasing ES with green infrastructure development in one neighborhood in Eugene, Oregon.

II. METHODS

2.1 Study Area

The City of Eugene covers 113 km^2 and has a population of 156,000, making it the second largest city in Oregon (U.S. Census Bureau, 2012). The Friendly Area Neighborhood (Figure 1), a low-density residential neighborhood (~8-10 dwelling units per hectare) in South Eugene, covers 3.7 km^2 and has a population of 7,000. The street layout in the Friendly Area Neighborhood is predominantly a traditional grid layout, and a vast majority of the housing stock consists of single-detached dwelling units. Sidewalks are dispersed irregularly throughout the neighborhood, although almost all streets have a vegetated planting strip located within the right-of-way. The median household income in the Friendly Area Neighborhood is $46,300 (Diebel, Norda, & Kretchmer, 2015), compared to $44,859 in the City of Eugene as a whole (U.S. Census Bureau, n.d.-b).

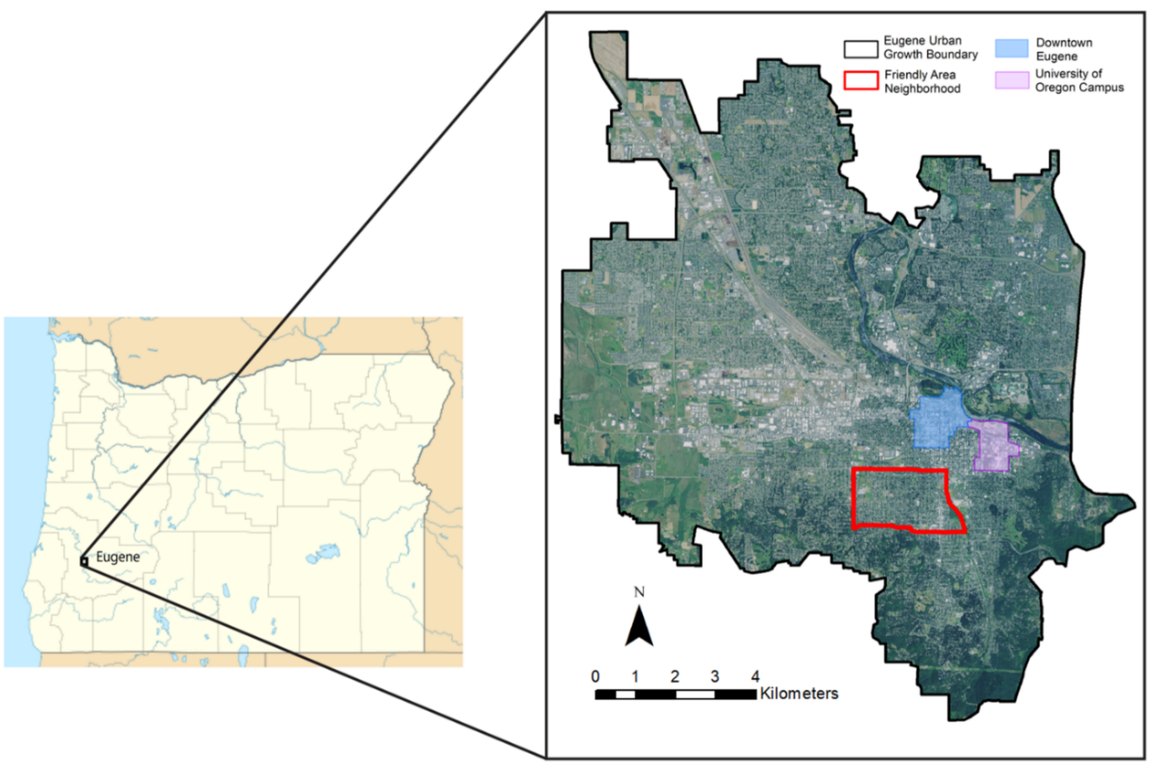


Figure 1: Friendly Area Neighborhood in Eugene, Oregon.

2.2 Public Green Space Mapping and Quantification

Although privately owned land plays an important role in providing UES (Davies, Edmondson, Heinemeyer, Leake, & Gaston, 2011; Zulian et al., 2017), its management is dictated predominantly by private property owners. Because of this, the focus of this study was devoted to public green space, where the provision of UES affects multiple stakeholders and is managed by the city. An inventory of all public green space was completed in the Friendly Area Neighborhood to evaluate the delivery of five ES—runoff retention, air purification, carbon storage, air temperature regulation, and recreation—by land cover type.

Multiple mapping strategies were used to inventory five distinct land cover types (Table 2) on public green space in the Friendly Area Neighborhood. Each street was systematically traversed, and lawn with no tree canopy cover located within the public right-of-way was geospatially located, measured, and catalogued using a handheld Global Positioning System. Because many tax lots in the Friendly Area Neighborhood do not have adjacent sidewalks, the boundary between tax lot and right-of-way can be difficult to distinguish. In these circumstances, the right-of-way boundary was defined by the water meter access box that is required for every property. LiDAR data were used to classify all remaining public green space—parks, schoolyards, and right-of-way planting strips —by land cover height (Table 2). Woodland areas were identified in places where clustered trees were clearly distinguishable from the available National Agricultural Imagery Program (NAIP) air photographs, and woodland parcel boundaries were demarcated in ESRI's ArcMap. Only one area within the neighborhood was classified as woodland, and several small clusters of trees may have been classified as 'tree' land cover, instead. From the spatial data, five ES were quantified for each land cover type using indicators and supply rates compiled by Derkzen et al. in 2015 (Table 2).

2.3 Resident Surveys

A random sample of 500 tax lots was generated using county tax lot data for the Friendly Area Neighborhood as a sampling frame. Tax lots that could be identified as non-residential (e.g. churches, government-owned properties, and businesses) were excluded. All remaining tax lots were assigned independently generated random numbers, and lots that were assigned the lowest 500 numbers were selected for the survey. Random sample surveys were administered to residents of the Friendly Area Neighborhood to determine the UES priorities for public green space, interest in UES enhancements on public green space, and the potential for increased funding for green infrastructure development.

Each of the 500 selected tax lots were visited once on a weekday between 5 and 7 PM. Non-residential properties, properties with 'no solicitors' signs, residents who declined to participate, and residential properties with no response were documented (Figure 2). Of the 500 selected tax lots, 475 were identified as residential, and 22% of residents (n=104) agreed to take the survey. Oral surveys were conducted with residents who agreed to participate, consistent with the Internal Review Board application approved by the Research Compliance Services department at the University of Oregon. While survey participants typically respond in writing, these surveys were conducted orally to ensure that the explanatory paragraphs (see Appendix A) were read completely and that all questions were answered. The survey questions were read aloud for participants, and answers were recorded by the researcher, although participants were allowed to read along on a blank copy.

The surveys consisted of two sections (Appendix A). In the first section, residents were asked to rank the importance of seventeen ES, using a five-point Likert scale to identify ES priorities within their neighborhood. In the second section, residents were asked whether they were interested in having public green spaces managed to increase the delivery of ES and whether they would be willing to devote funds, either through personal contributions or tax measures, to public green infrastructure development projects that increase the provision of ES. In addition, residents were asked to gauge their interest in participating in the planning, implementation, and maintenance of public projects designed to increase the delivery of ES.

2.3.1 Residential Survey Analysis

Statistical analyses were conducted using Stata to determine residents' ES priorities, interest in ES enhancements on public green space, and stated willingness to provide revenue for public works projects that promote ES. Mean importance for each ES was generated by assigning values for each Likert response choice (1 – Very Unimportant; 2 – Moderately Unimportant; 3 – Neutral; 4 – Moderately Important; 5 – Very Important). ES priorities for public green space were identified using single-sample t-tests to compare mean Likert scores for each ES to the mean Likert score for all the ES combined. Additional single-sample t-tests were used to compare means aggregated for ES classification types (provisioning, regulating, cultural, and supporting) and for ES bundles provided by the land cover types from Table 1. Each grouping of ES was tested for internal consistency using Cronbach's alpha (α), where values above 0.7 were regarded as acceptable (Loewenthal, 2001). Results from the second section of the survey were used to determine residents' interest in green infrastructure development that increases the delivery of ES in their neighborhood.

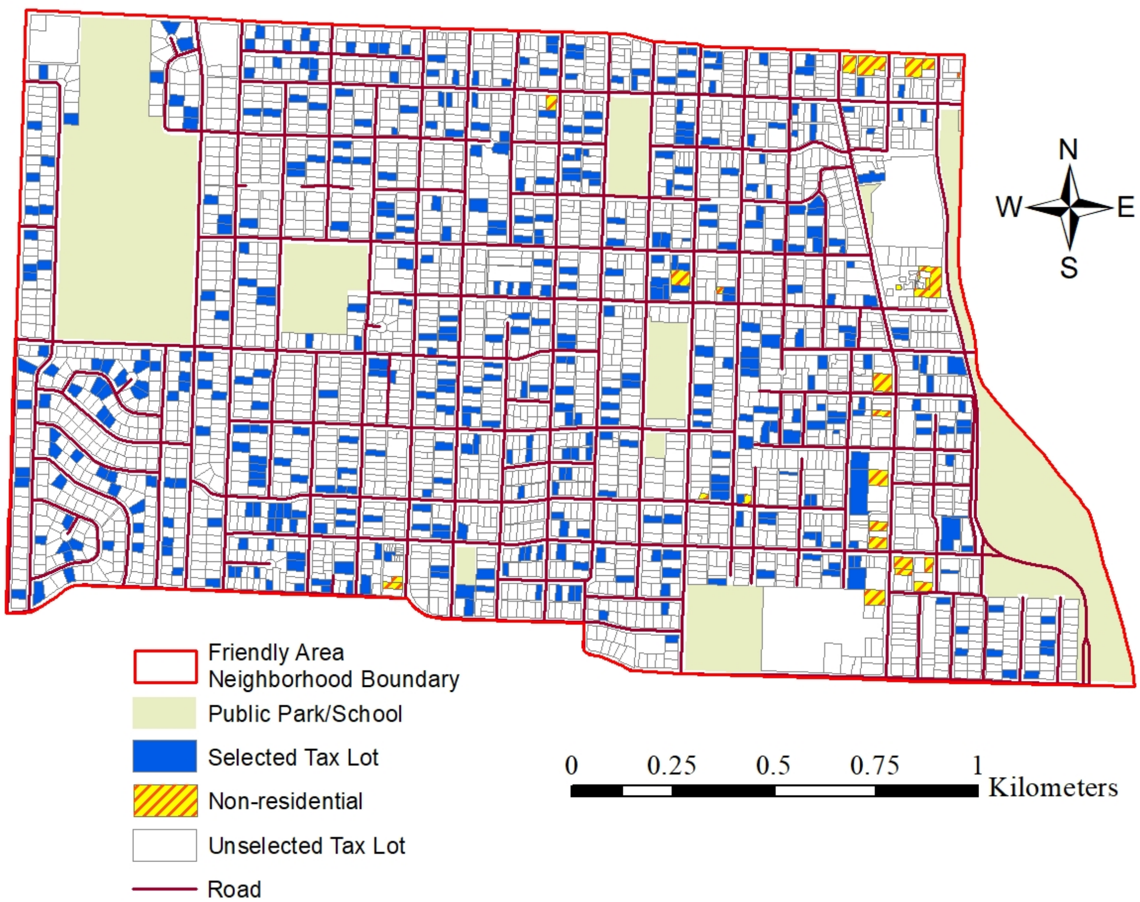


Figure 2: Tax lots selected for residential survey in the Friendly Area Neighborhood.

2.4 Delphi Method

A Delphi method analysis, or an iterative survey process developed to consult with a group of individuals, knowledgeable on a given topic (Dalkey, 1969; Thrall & McCartney, 1991), was conducted to identify UES and green infrastructure development priorities—not just for the Friendly Area Neighborhood, but for the city of Eugene as a whole—among representatives from the agencies responsible for the planning, implementation, and management of public green spaces in Eugene. Participants were selected for the Delphi method on the basis of their expertise in the fields of public policy and green space management in Eugene. Of the 34 individuals invited to participate from the City of Eugene's Public Works Department, the Eugene City Council, the University of Oregon Landscape Architecture Department, and several local environmental nonprofits, 15 agreed to answer and comment on two surveys. Of the 15 Delphi participants, there were nine representatives from the City of Eugene Public Works Department, which includes the Parks and Open Space, Stormwater Management, and Urban Forestry; two from the City of Eugene Planning and Development Department; two from local environmental non-profits; one from the Eugene City Council; and one from the University of Oregon Landscape Architecture department. While the Delphi analysis included a diverse group of stakeholders, this by no means included every stakeholder that interacts with public green space in some capacity (e.g. utility service managers).

The first survey (Appendix B) consisted of seven open-ended questions allowing participants to elucidate their positions regarding the following: UES provided by public green space, benefits of and concerns about lawn planted on public property, benefits and barriers to the conversion of lawn to alternative planting regimes, and potential methods to overcome barriers to green infrastructure development. Alternative planting regimes were not specifically defined in the survey, as conversion to different land cover types can provide different ES bundles (Table 1). In addition, participants were supplied with the list of seventeen ES provided in the resident surveys and asked to rank them in order of importance for public green space management in Eugene.

Summaries of responses from the first survey, including a selection of representative responses, were provided with the second survey (Appendix C). Fourteen questions were generated for the second survey (Appendix C), based on the responses to the first survey, distinguishing between management of public green space in parks and on right-of-way planting strips. Participants were asked to select from the collective responses generated in the prior survey—the quantity of responses varied between questions (see Appendix D)—and were encouraged to consider their second-round responses in light of the collective data from the first-round survey.

No particular threshold of agreement defines ‘consensus’ in the Delphi method, and levels vary from a simple majority to 95% agreement, according to the particular conditions of each project (Loughlin & Moore, 1979; Putnam, Spiegel, & Bruininks, 2016; Stewart et al., 1999; von der Gracht, 2012). Because of these considerations, combined with the diversity of expertise within the participant group, a consensus threshold of 2/3 was chosen, representing a value consistent with practices in many city governments (*The Charter of the City of Ashland*, 2006; *Charter of the City of Seattle*, 2013; *Eugene Charter*, 2002).

2.5 Land Cover Conversion Scenarios

Scenarios were generated to identify the potential increase in ES associated with the conversion of lawn to alternative land cover types. Selection of conversion scenarios were guided by the ES priorities established from the combined results of resident surveys and the Delphi analysis. The ES identified as priorities by both stakeholder groups were each given an informed weight based on their potential contributions to human health and well-being in the Friendly Area Neighborhood (0=unimportant; 1=low; 2=medium; 3=high). For example, carbon storage received an informed weight of “0”, because carbon sequestration from urban green space is negligible compared to urban carbon emissions (Nowak, 1994; Nowak & Dwyer, 2007; Nowak et al., 2002; Zhao et al., 2016), whereas air purification received a high informed weight, due to the potential for urban forests to address air quality issues in the region and reduce respiratory- and cardiovascular-related health complications (Nowak et al., 2014),.

Five alternative land cover scenarios, described in Section 3.5, were generated to assess the potential for increasing the provision of ES with the highest informed weights, by converting lawn to alternative land cover types. Land cover conversion alternatives were evaluated in comparison to the existing land cover conditions and to one another. UES supply rates from Derkzen et al. (2015) were used to calculate changes in air purification, runoff retention, carbon storage, and recreation value associated with the conversion of lawn to different land cover types. All land area converted in each conversion scenario was multiplied by the respective supply rate, and the value of each ES provided by lawn from that converted area was subtracted to quantify the change of each ES.

III. RESULTS

3.1 Public Green Space Inventory

To assess the delivery of ES by land cover type, ground and LiDAR spatial analyses were conducted in the Friendly Area Neighborhood. Results showed that lawn is the dominant land cover type on public green space, typical of low-density residential development (Robbins & Birkenholtz, 2003). Of the 68.1 hectares (ha) of public green space, 49.4% (33.6 ha) were covered by lawn with no canopy cover, 27.6% (18.8 ha) by trees, 8.7% by tall shrubs (5.9 ha), 7.9% by short shrubs (5.4 ha), and 6.3% (4.3 ha) by woodland (Table 3; Figure 3-4). All woodland and a vast majority of lawn (85.5%) was located in parks and school yards, while 84.7% of all non-woodland tree canopy, 87.8% of short shrubs, and 82.4% tall shrubs was located within the right-of-way.

Every land cover type delivers each ES at a unique rate (Derkzen, M. L. et al., 2015; Table 2), and the total quantity of ES provided by each land cover type is dependent on the coverage area and distribution. Overall, public green space in the Friendly Area Neighborhood provided over two-thousand metric tons of carbon storage; removed approximately 2,500 kilograms per year of atmospheric particulate under 10 microns; and retained over 1.6 million liters of stormwater during a 12-millimeter storm event (Table 3). Lawn covered nearly half of the land cover and provided about half of the runoff retention and recreation value but only about one-fifth of the air purification services and less than 2% of the carbon storage (Table 3). By comparison, trees covered only about one-quarter of the green space but supplied over half of the air purification and carbon storage, and approximately one-third of the cooling services and runoff retention but provided less than 20% of the recreation services. Large and small shrubs each covered less than 10% of the total public green space and provided ES relatively proportional to their coverage area. Woodland was the least abundant land cover type, yet it provided 10.6% of the recreation value, more than was provided by both tall and short shrubs. Although carbon storage has been identified as insignificant compared to other ES, woodland provided 19.3% of the carbon storage, more than 12 times the quantity of carbon stored in lawn.

Table 3: Quantity of five ecosystem services in the Friendly Area Neighborhood

Land Cover Type	**Area** hectares *% of total LC*	**Air Purification** kg yr^{-1} *%*	**Carbon Storage** kg *%*	**Runoff Retention** L/12 mm storm *%*	**Cooling Fraction** *%*	**Recreation** *%*
Tree	18.8 *27.6*	1436 *57.5*	2,002,524 *57.2*	1,637,402 *29.6*	*36.7*	*19.3*
Woodland	4.3 *6.3*	145 *5.8*	674,852 *19.3*	375,878 *6.8*	*8.4*	*10.6*
Tall Shrub	5.9 *8.7*	229 *9.2*	463,189 *13.2*	434,054 *7.8*	*11.6*	*7.1*
Short Shrub	5.4 *7.9*	212 *8.5*	302,581 *8.6*	393,733 *7.1*	*10.5*	*6.2*
Lawn/ Herbaceous	33.6 *49.4*	476 *19.0*	57,167 *1.6*	2,690,200 *48.6*	*32.8*	*56.9*
TOTAL	68.1 *100*	2498 *100*	3,500,314 *100*	5,531,268 *100*	*100*	*100*

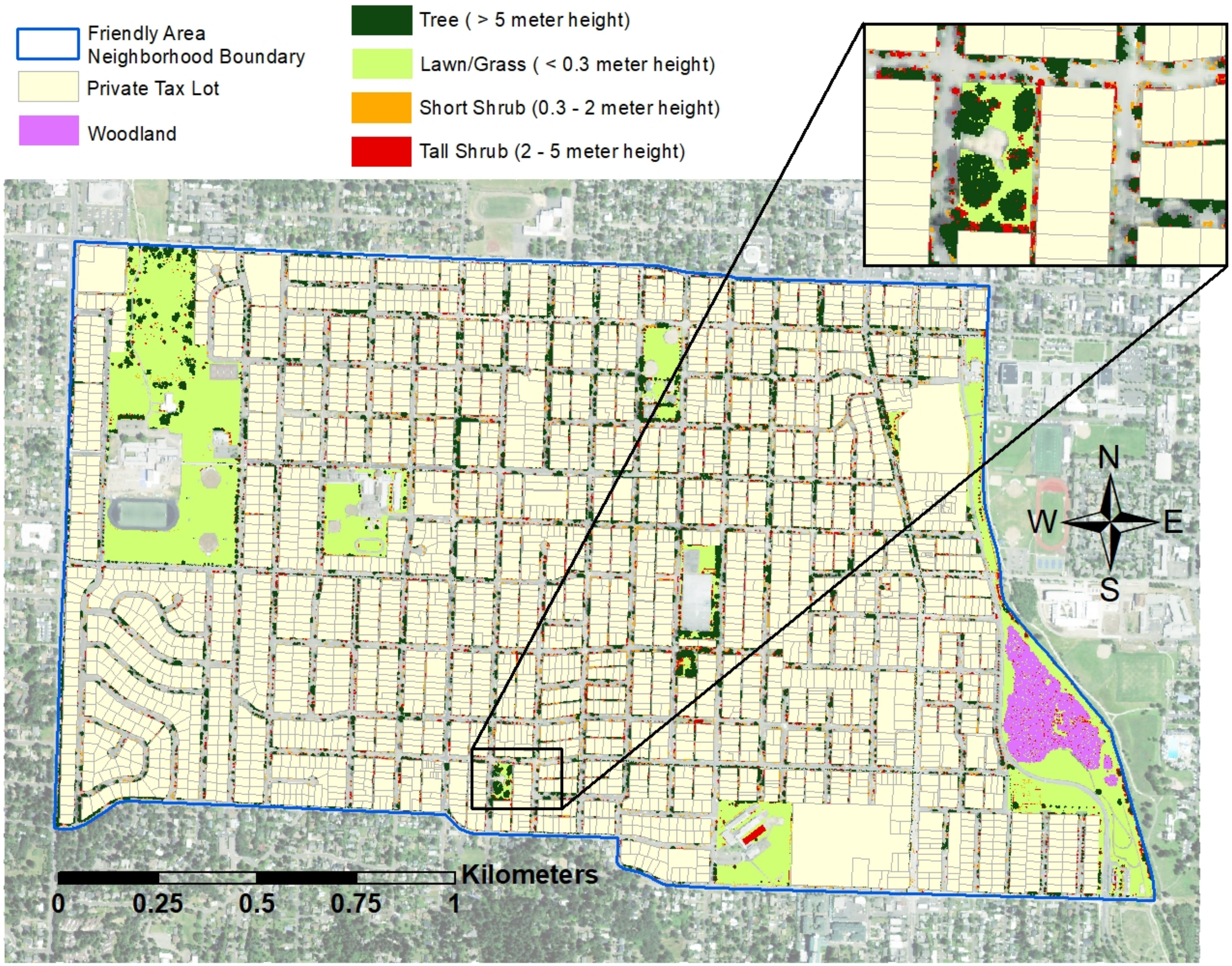


Figure 3: Land cover types in the Friendly Area Neighborhood, identified using LiDAR data.

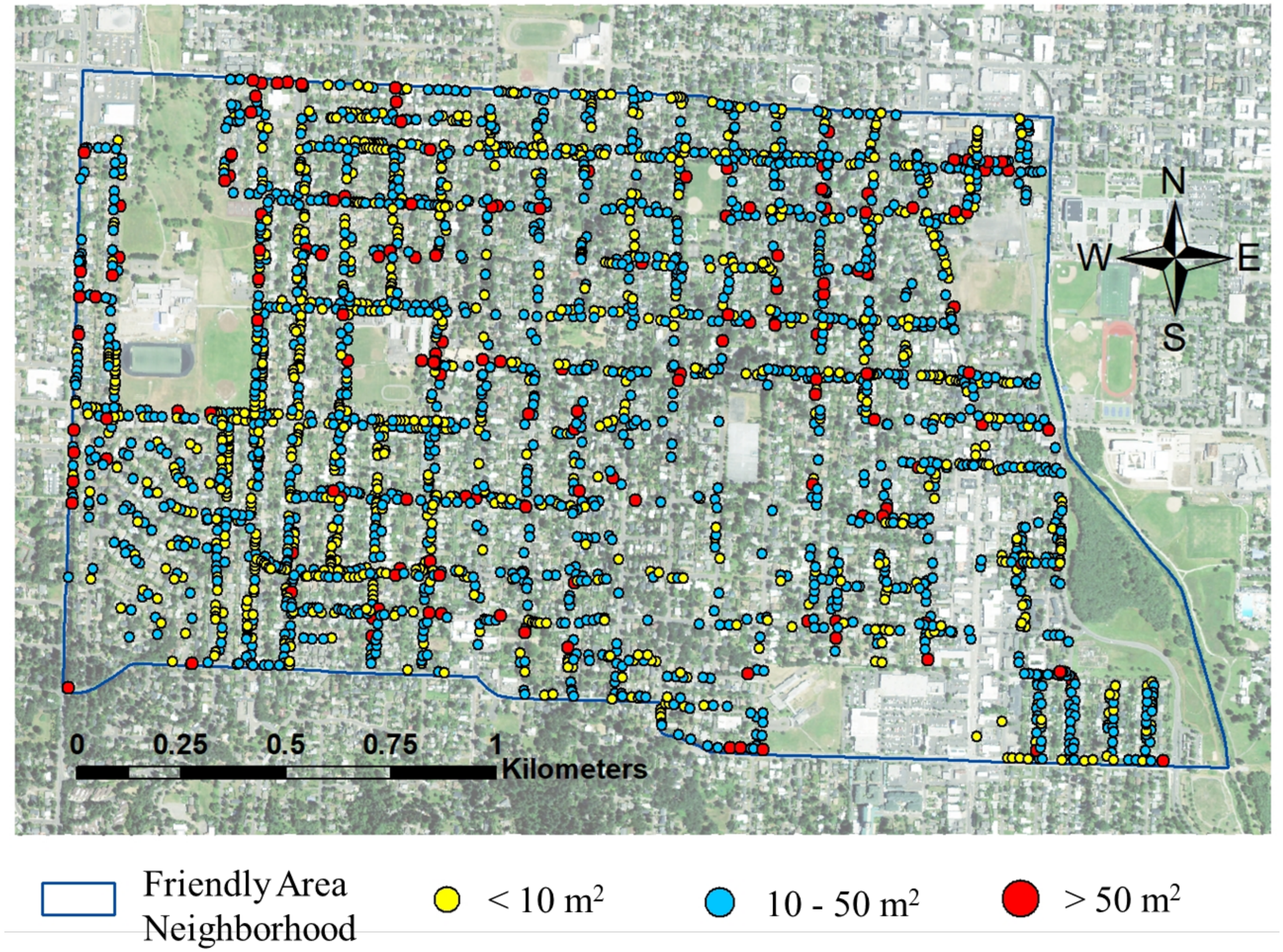


Figure 4: Lawn parcels in the right-of-way in the Friendly Area Neighborhood.

3.2 Resident Surveys - Ecosystem Service Priorities

The first objective of the survey was to establish residents' ES priorities, from the list of seventeen ES provided (Table 4; Appendix A), for public green space in their neighborhood, although no distinctions were made between green spaces located in parks, schoolyards, and right-of-way planting strips. Survey respondents (n=104) identified stormwater purification, air purification, and pollinator habitat as the most critical ES that should be provided by public green space (Table 4; Figure 5). In addition, residents prioritized increasing carbon sequestration over air temperature regulation, soil health, and flood prevention. Among the supporting services, in addition to improving pollinator habitat, residents identified improving habitat for birds and native plant species as priorities. While cultural services were not generally prioritized by residents for public green space, providing space for outdoor recreation and education was valued significantly above the overall ES mean (p=0.0008). Survey respondents demonstrated a clear preference for regulating and supporting services on public green space, while cultural and provisioning services were viewed as relatively unimportant (Table 4). Based on residents' ES preferences, the ES bundles, as identified by a literature review (see Table 1), provided by trees, lawns, rain gardens, woodlands, prairies, and wetlands were all valued above the overall ES mean and had p-values below 0.01 (Table 5). This implies that, based solely on residents' ES preferences, they would approve of green infrastructure development that incorporated any of the above land cover types into public green space.

Table 4: Friendly Area Neighborhood residents' ecosystem service priorities (n=104)

Ecosystem Service	Mean	Standard Deviation	95% Confidence Interval	*p*-value [b]
Supporting Services (α=0.77)**	4.63	0.54	4.53 – 4.74	0.0006
*Pollinator Habitat**	4.84	0.54	4.73 – 4.94	0.0000
*Bird Habitat***	4.69	0.67	4.56 – 4.82	0.0002
*Native Species**	4.59	0.75	4.45 – 4.74	0.0448
Plant Diversity	4.41	0.81	4.26 – 4.57	0.7120
Regulating Services (α=0.81)*	4.56	0.53	4.46 – 4.67	0.0236
*Stormwater Purification**	4.86	0.40	4.78 – 4.93	0.0000
*Air Purification**	4.71	0.63	4.59 – 4.83	0.0000
*Carbon Sequestration**	4.63	0.77	4.48 – 4.77	0.0170
Air Temperature Regulation	4.43	0.76	4.28 – 4.58	0.8925
Soil Health	4.40	0.83	4.24 – 4.56	0.5867
Flood Reduction	4.37	0.92	4.19 – 4.55	0.4162
Provisioning Services (α=0.85)	4.25	0.84	4.08 – 4.41	0.0185
Fruit Production	4.30	0.81	4.14 – 4.46	0.0717
Vegetable Production+	4.19	0.99	4.00 – 4.38	0.0110
Cultural Services (α=0.80)	4.23	0.64	4.10 – 4.36	0.0011
*Outdoor Recreation/Education**	4.65	0.62	4.53 – 4.77	0.0008
Natural Beauty/Aesthetics	4.50	0.74	4.35 – 4.64	0.4740
Community Identity+	4.23	0.96	4.04 – 4.42	0.0261
Noise Reduction+	4.03	0.98	3.84 – 4.22	0.0000
Privacy/Seclusion+	3.70	0.98	3.51 – 3.89	0.0000

Cronbach's alpha expressed as α

[b] Single-sample t-tests used to compare ecosystem services to overall ecosystem service mean (4.44279)

* p-value <0.05; significantly greater than overall ES mean

\+ p-value <0.05; significantly less than overall ES mean

Table 5: Friendly Area Neighborhood residents' land cover priorities

Ecosystem Service Bundles by Land Cover Type [a]	Mean	Standard Deviation	95% Confidence Interval	p-value [b]
Lawn/Herbaceous (α=0.75)	4.60	0.49	4.51 – 4.70	0.0011
Street Tree (α=0.78)	4.60	0.53	4.50 – 4.70	0.0031
Swale/Raingarden (α=0.77)	4.61	0.58	4.50 – 4.72	0.0037
Woodland (α=0.85)	4.57	0.48	4.48 – 4.67	0.0078
Wetland (α=0.82)	4.62	0.46	4.53 – 4.71	0.0001
Prairie/Savanna (α=0.81)	4.64	0.46	4.55 – 4.73	0.0000

Cronbach's alpha expressed as α

[a] Ecosystem service bundles by land cover type as documented in Table 1

[b] Single-sample t-tests used to compare ES bundles to overall ES mean (4.44279)

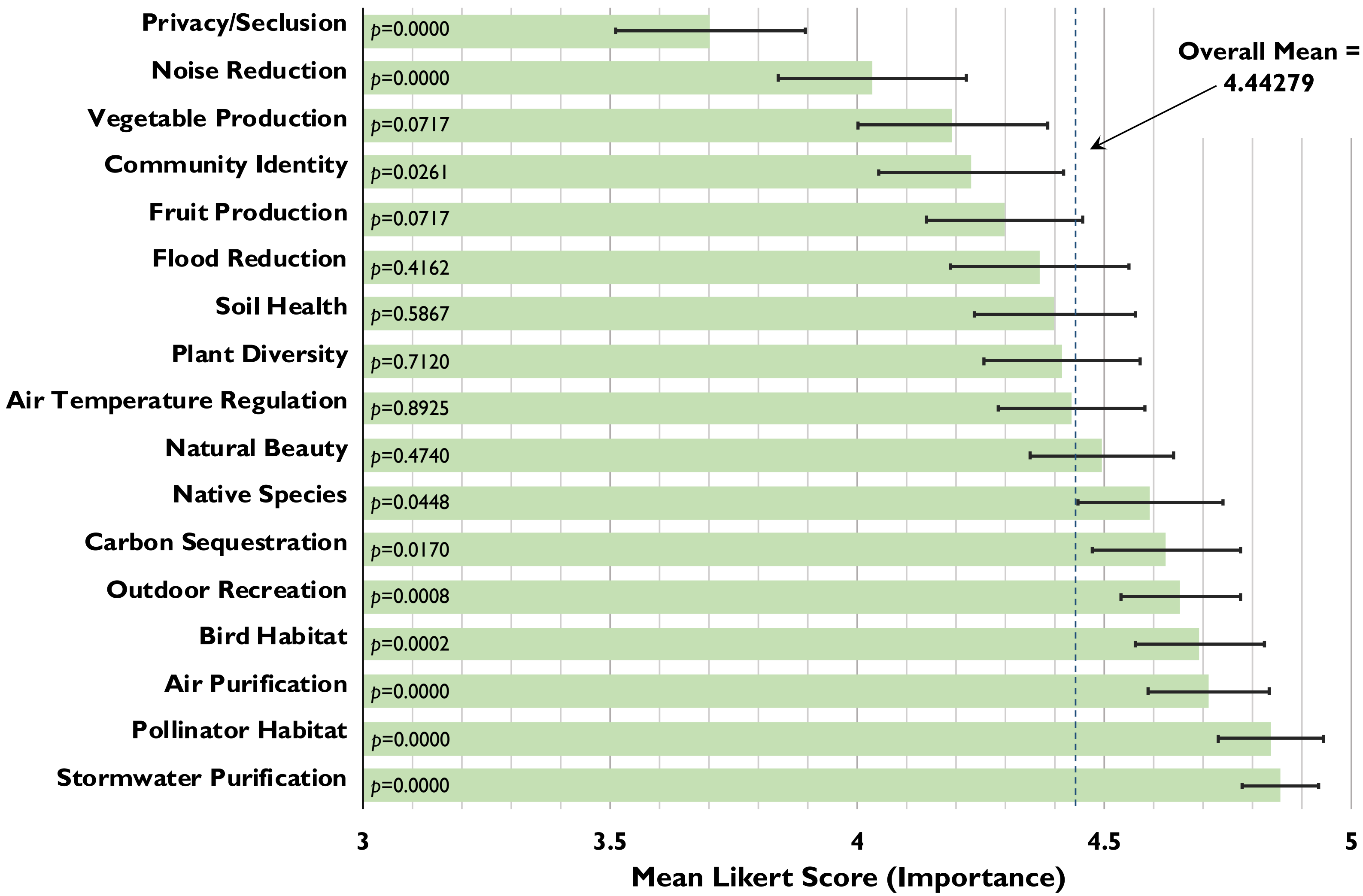


Figure 5: Ecosystem service priorities identified by Friendly Area Neighborhood residents using a Likert scale, where 1 was very unimportant, 2 was moderately unimportant, 3 was neutral, 4 was moderately important, and 5 was very important.

3.2.1 Resident Surveys - Support for Green Infrastructure Development

The second objective of the resident survey was to evaluate residents' willingness to support green infrastructure development on public green space through financial contributions and volunteering. Residents' responses indicated strong support for green infrastructure development that would increase the delivery of ES on public green space. Overall, 87.5% stated that they would be willing to financially support green infrastructure development, 30.8% out-of-pocket and 56.7% via a tax measure that would direct funding to public works projects designed to increase the delivery of ES (Figure 6). In addition, a vast majority of respondents (81.6%) expressed interest in volunteering to implement and maintain green infrastructure projects in the neighborhood, 65% of whom stated that they were willing to volunteer for five or more hours per year (Figure 7).

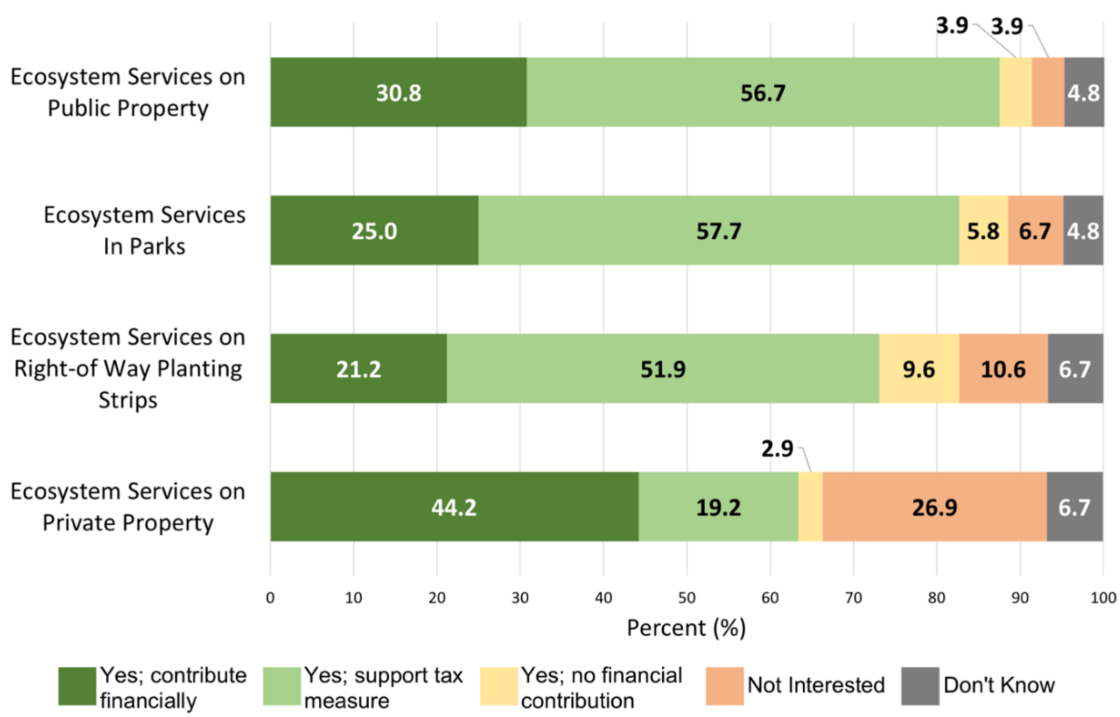


Figure 6: Friendly Area Neighborhood residents' (n=104) stated willingness to financially support green infrastructure development that increases ecosystem services.

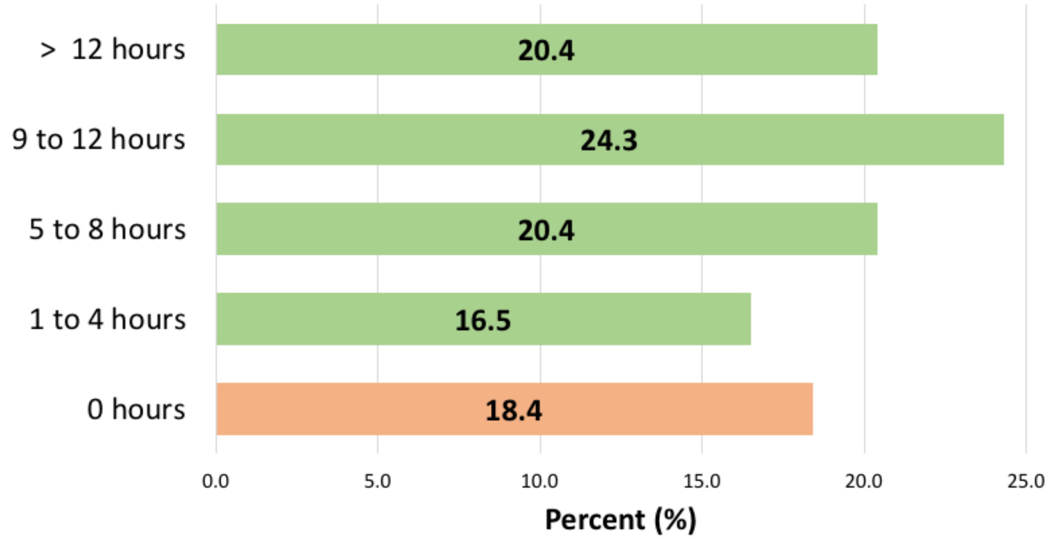


Figure 7: Friendly Area Neighborhood residents' (n=104) stated willingness to volunteer (hours/year) for public green infrastructure projects.

3.3 Delphi Analysis

A Delphi analysis was used to evaluate ES priorities and obstacles to green infrastructure development from the perspective of city planners, nonprofit managers, and other professionals with expertise in public green space management. Through two survey iterations, the group of environmental managers, analysts, designers, and planners generated consensus (≥66.7% agreement) regarding priority ES for public green space; primary benefits of and concerns with lawn; and benefits, barriers, and strategies to address barriers to green infrastructure development, differentiating between management of parks and right-of-way planting strips.

3.3.1 Delphi Analysis - Ecosystem Service Priorities

After the first-round survey, the six ES that were determined to be non-priorities included noise reduction, community identity, vegetable production, fruit production, improved soil health, and privacy (Appendix C). These were removed from the list of possible priority ES for the second survey. In the second-round survey, Delphi participants identified the reduction of stormwater pollution as the most important ES (≥ 80% agreement) to be provided both by right-of-way planting strips and by parks (Table 6; Figure 8). Increasing carbon sequestration, improving air quality, supporting native species, providing natural beauty, and reducing flooding also generated consensus as priority ES for both parks and right-of-way planting strips. Providing shade as a means of cooling was classified as a priority ES for right-of-way planting strips, with 73.3% agreement, but did not reach the threshold for consensus in parks. Participants identified parks as valuable spaces for providing habitat (73.3% agreement), as well as educational opportunities (66.7% agreement). Outdoor recreation, plant diversity, erosion control, and physical and mental health benefits did not receive enough support to reach the consensus threshold and were classified as non-priorities.

Table 6: Ecosystem services that generated consensus among Delphi participants (n=15)

Priority Ecosystem Services	First Survey		Second Survey	
	Ranking Mean*	Ranking Median*	Percent of Respondents for Right-of-Way (%)	Percent of Respondents for Parks (%)
Stormwater Purification	3.2	2.0	86.7	80.0
Carbon Sequestration	6.1	4.0	66.7	80.0
Air Purification	3.9	3.0	73.3	66.7
Native Species	6.6	7.5	73.3	73.3
Aesthetic/Natural Beauty	7.7	8.0	73.3	66.7
Flood Reduction	7.9	6.0	66.7	66.7
Air Temperature Regulation	5.4	4.5	73.3	-
Habitat for Birds/Pollinators	8.0	7.0	-	73.3
Educational Opportunities	N/A	N/A	-	66.7

Consensus defined as ≥ 66.7%

*Ranking mean/median of 1 is highest possible ranking and 17 is lowest

- Percent of respondents < 66.7%

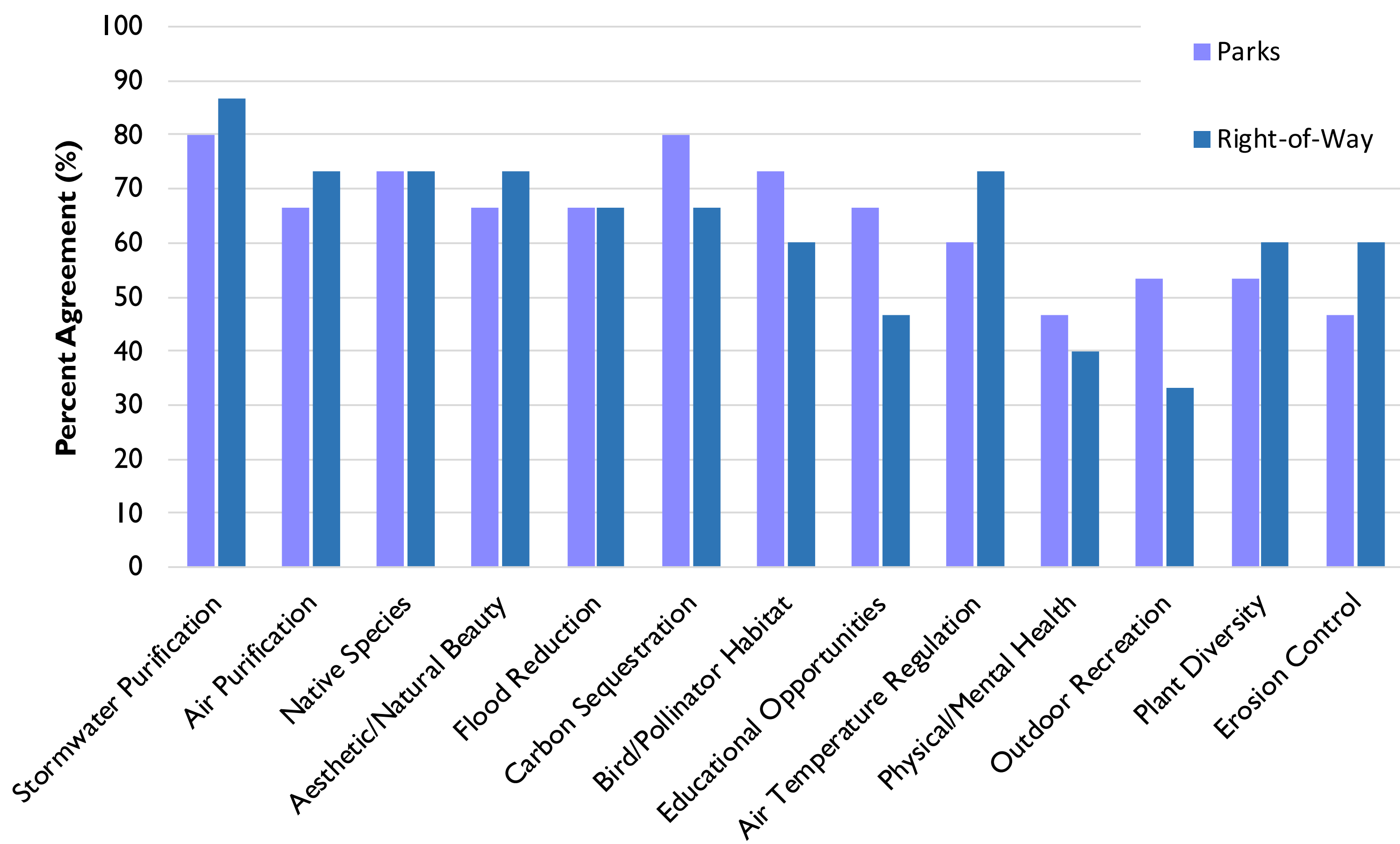


Figure 8: Percent of Delphi participants (n=15) in the second survey that identified each of the above ecosystem services as important for public green space in Eugene, Oregon, distinguishing between green space located in parks and on right-of-way planting strips.

3.3.2 Delphi Analysis - Lawn in Public Green Space Management

Participants were asked to consider the benefits of and problems with lawn planted on public space. Providing space for recreation (93.3% agreement) and gathering (73.3% agreement), as well as the ease of maintenance (66.7% agreement), were identified as the primary benefits of lawn in parks (Table 7; Appendix D). Improved safety and sight lines were the only benefits of lawn on right-of-way planting strips that reached the consensus threshold with 86.7% agreement. The principal concern regarding lawn on public green space was that it provides fewer regulating services (e.g. air and water pollution filtration, carbon sequestration, and flood reduction) than alternative planting regimes. In addition, irrigation requirements and the lack of biodiversity were identified as concerns regarding lawn in parks and on right-of-way planting strips. Two-thirds of participants agreed that the impacts from fertilizers, pesticides, and herbicides were a concern on the right-of-way planting strips, but not in parks. The lack of concern regarding the use of sprays in parks was likely because the City of Eugene received the "Salmon Safe Certification", given by a third-party agency for park management and maintenance practices that minimize the use of pesticides, herbicides, and fertilizers (City of Eugene, n.d.-d). For several of the responses, the amount of agreement changed abruptly between the first and second surveys (e.g. biodiversity, quality design and maintenance plans), likely because in the first survey, participants were asked to generate their own responses, and in the second survey, they were asked to choose from the list of collective responses (see Appendices C and D).

Table 7: Consensus responses (n=15) from the Delphi analysis regarding benefits and concerns with lawn planted on public space, as well as benefits, barriers, and potential strategies to address barriers to the conversion of lawn to alternative land cover types

Delphi Responses	First Survey	Second Survey	
	Percent of Respondents (%)	Percent of Respondents for Right-of-Way (%)	Percent of Respondents for Parks (%)
Benefits of Lawn			
Space for Recreation	73.3	-	93.3
Safety/Sight Lines	13.3	86.7	-
Space for Gathering	20.0	-	73.3
Ease of Maintenance	26.7	-	66.7
Concerns with Lawn			
Provides Fewer Regulatory Services than Alternative Planting Regimes	33.3	86.7	86.7
Irrigation Requirements	60.0	66.7	66.7
Low Biodiversity	20.0	66.7	66.7
Impacts from Fertilizers/Pesticides/Herbicides	26.7	66.7	-
Conversion Benefits			
Increased Biodiversity	26.7	80.0	80.0
Improved Habitat for Birds/Pollinators	33.3	-	73.3
Improved/Diversified Aesthetics	20.0	66.7	-
Stormwater Runoff Reduction	73.3	66.7	-
Conversion Barriers			
Impaired Safety/Sight Lines	53.3	66.7	-
Increased Maintenance Complexity[*]	53.3	60.0	53.3
Cost of Transition[*]	40.0	53.3	53.3
Increased Opportunity for Illegal Camping[*]	53.3	-	53.3
Addressing Barriers			
Education, Marketing, and Outreach	66.7	66.7	80.0
Quality Design and Maintenance Plans	20.0	73.3	80.0
Lawn Conversion Support [+]	N/A	93.3	86.7

Consensus defined as ≥ 66.7%

- Percent of respondents < 66.7%

[*] Simple majority; no consensus identified

[+] Includes responses supporting partial and complete lawn conversion

3.3.3 Delphi Analysis - Green Infrastructure Development

As highlighted by the Delphi participants' concerns regarding lawn maintenance and the lack of regulating and supporting services provided by lawns, respondents agreed that replacing lawn with alternative planting regimes could increase biodiversity (80% agreement) and improve habitat in parks (73.3% agreement), while reducing stormwater runoff along right-of-way planting strips (Table 7; Appendix D), achievable by replacing lawn with stormwater retention facilities. The possibility of impaired sight lines was identified as a safety concern and was the only barrier associated with conversion of lawn to alternative planting regimes on right-of-way planting strips (66.7% agreement). While a majority of participants agreed (53.3%) that converting lawn to alternative planting regimes would increase maintenance time, complexity, and cost during the transition period, agreement regarding the importance of these barriers did not reach the consensus threshold. To address these barriers to green infrastructure development on public green space, participants suggested "increased education, marketing, and outreach", as well as "quality design and maintenance plans". Overall, 93.3% and 86.7% of participants supported the conversion of at least some lawn to alternative planting regimes on right-of-way planting strips and in parks, respectively.

3.4 Land Cover Conversion Scenarios

Land cover conservation scenarios were generated using the combined ES priorities from the resident surveys and Delphi analysis. Each ES, prioritized by either stakeholder groups, was assigned an informed weight, from "0" to "3" (Table 8), based on the potential benefits associated with the increase of each ES through green infrastructure development (Table 8).

Air purification and stormwater pollutant removal were given the highest informed weights. The removal of atmospheric particulate matter has appreciable health implications, particularly in Eugene, identified as one of the 25 worst cities in the United States for short-term, fine particulate air pollution (American Lung Association, 2018). As such, air purification was assessed the highest informed weight of “3” (Table 8). The City of Eugene is required by the National Pollution Discharge Elimination System (NPDES) permit to “reduce the discharge of pollutants from the municipal system to the maximum extent possible” (City of Eugene, n.d.-b). Although residential neighborhoods contribute far fewer stormwater pollutants (e.g. total suspended solids) than roads with heavy traffic (Wang, S., He, Ai, Wang, & Zhang, 2013), lower-density development contributes more runoff and effects more of the overall watershed than higher-density developments (Richards, 2006). The City of Eugene should prioritize stormwater pollution reduction measures in areas with higher traffic concentration but should also consider stormwater purification measures for the Friendly Area Neighborhood. Because of these considerations, stormwater purification received an informed weight of “2”.

Carbon sequestration, flood reduction, air temperature regulation, and outdoor recreation were all assigned the lowest informed weight of “0”. Carbon storage from urban green space provides negligible offset to urban carbon emissions (Nowak et al., 2002; Zhao et al., 2016), and green infrastructure cannot adequately address the impacts of carbon emissions on climate. The urban heat island effect has been increasingly discussed as a major concern for municipalities, and recent research identified certain areas in Eugene that remain hotter than other areas, most notably downtown and in West Eugene; however, air temperature regulation is not a major concern for the Friendly Area Neighborhood (Darling, 2017). The Friendly Area Neighborhood is in an area with minimal flooding risk, according to FEMA hazard maps for the City of Eugene (FEMA, 2017). Virtually all (94.5%) of the area in the Friendly Area Neighborhood is located within a 5-minute walking distance, or 0.4 kilometers, from public open space (e.g. parks or schoolyards; Figure 9), and residents have 54 m^2 of green space per capita in parks and schoolyards, which is above the World Health Organization's ideal target of 50 m^2 (WHO, 2010), demonstrating that access outdoor recreation is already adequate.

All remaining ES prioritized by stakeholders were assigned an informed weight of "1", as they have the potential to improve human wellbeing (Kothencz, Kolcsar, Cabrera-Barona, & Szilassi, 2017), as well as urban ecological resilience (Alberti & Marzluff, 2004; Hall et al., 2017; Hunter, 2011), but could not be identified as critical to meeting federal environmental standards.

Table 8: Informed weighting for priority ecosystem services

Ecosystem Service	**Informed Weight** (0=non-priority; 1=low 2=medium; 3=high)
Air Purification	3
Stormwater Purification	2
Habitat for Birds/Pollinators	1
Increased Quantity of Native Plant Species	1
Aesthetic/Natural Beauty	1
Air Temperature Regulation	0
Outdoor Recreation and Education	0
Flood Reduction	0
Carbon Sequestration	0

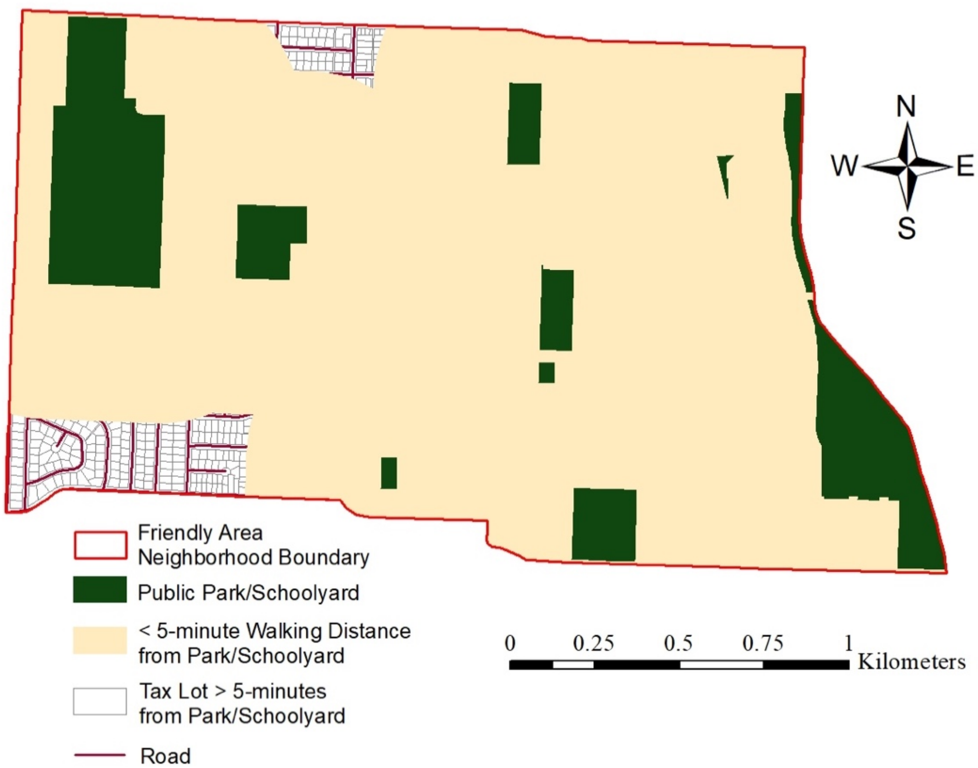


Figure 9: Area in the Friendly Neighborhood that is within a 5-minute walk to public open space (e.g. parks and schoolyards).

There are five ES that emerge as priorities from the informed weighting process, yet only air purification can be assessed quantitatively, using the Derkzen et al. (2015) supply rates (see Table 2). Although stormwater purification refers to the *pollutants* (e.g. heavy metals, nitrogen, phosphorus, and suspended solids) removed by green infrastructure and runoff retention refers to the *volume* of stormwater removed by green cover, the National Academy of Sciences (2009) recommends that the United States Environmental Protection Agency use stormwater runoff volume as a proxy for stormwater pollutant loading. Based on this recommendation, runoff retention was used in the place of stormwater purification for the conversion scenarios.

Although each land cover type in the green space inventory of the Friendly Area Neighborhood has a similar capacity to retain runoff (see Table 2), Zellner et al. (2016)

demonstrated that converting 15% of the area adjacent to roads to stormwater retention facilities (i.e. vegetated swales, raingardens, and biofiltration facilities), designed with curb cuts to allow runoff from roads into planted detention areas, could absorb over 50% of precipitation and the associated pollutants accumulated on roadways during a 9.4 centimeter, twenty-four-hour storm event, roughly equivalent to a 5-year storm event in Eugene (Miller, Frederick, & Tracey, 1973). Quantifying stormwater runoff and pollutant retention associated with specially designed stormwater facilities was outside the scope of the quantification method established by Derkzen et al. (2015); however, converting the 4.9 hectares of lawn, or 16% of the total green space adjacent to roads in the Friendly Area Neighborhood, located in right-of-way strips to stormwater infiltration facilities would address residents' and Delphi participants' priority of reducing stormwater-related pollution. For all five conversion scenarios generated in this section, it is assumed that the 4.9 hectares of lawn along the right-of-way would be converted to stormwater facilities and will therefore not be accounted for quantitatively.

All five development scenarios generated for this study were designed to increase air purification services for public green space. The first scenario attempts to maximize air purification services by converting all lawn, aside from lawn on the right-of-way, to woodland (Table 9). The second, third, and fourth scenarios are all attempts to strategically convert lawn to maximize air purification services, while minimizing conversion area, as only one Delphi participant supported the conversion of all lawn in parks to alternative planting regimes. According to the quantification method established by Derkzen et al. (2015), plants within 50-meters of roads provide twice as much air purification as plants further from roads. Strategic Air Purification 1 (see Table 9) evaluates the benefits of converting all lawn within 50-meters of roads to woodland, and Strategic Air Purification 2 and 3 evaluate the benefits associated with converting 50% of lawn within 50-meters of roads to woodland and dispersed trees, respectively. The final land conversion alternative, the Diversity Planting scenario (see Table 9), involves the conversion of 5 hectares of lawn to woodland, 5 hectares to trees, 2.5 hectares to short shrubs, and 2.5 hectares to tall shrubs, 50% of which is located within 50-meters of roads.

Table 9: Ecosystem service changes associated with the conversion of lawn in the Friendly Area Neighborhood

Conversion Alternatives	**Hectares Converted** Ha	**Air Purification** total kg yr^{-1} *% change*	**Carbon Storage** total kg *% change*	**Runoff Retention** L/12mm storm *% change*	**Recreation** *% change*
No Change[+]	0	2,498 *0*	3,500,314 *0*	5,531,268 *0*	*0*
Maximum Air Purification [b]	28.8	3,268 *30.9*	7,942805 *126.9*	5,732,546 *3.6*	*7.3*
Strategic Air Purification 1 [d]	14.3	3,010 *20.5*	5,711,877 *63.2*	5,631,468 *1.8*	*3.6*
Strategic Air Purification 2 [f]	7.2	2,754 10.3	4,606 31.6	5,581,368 0.9	*1.8*
Strategic Air Purification 3 [g]	7.2	2,937 *17.6*	4,249,669 *21.4*	5,581,368 *0.9*	*-2.1*
Diversity Planting [h]	15.0	2,948 *18.0*	5,122,814 *46.4*	5,566,268 *0.6*	*0.1*

[+] Provision of ES under current land cover distribution with no conversion.

[b] All herbaceous/lawn land cover converted to woodland.

[d] All herbaceous/lawn land cover type within 50-meters of road converted to woodland.

[f] 50% of herbaceous/lawn land cover within 50-meters of road converted to woodland cover.

[g] 50% of herbaceous/lawn land cover within 50-meters of road converted to dispersed tree cover.

[h] Five hectares converted to tree cover; five hectares converted to woodland; 2.5 hectares converted to tall shrub; and 2.5 hectares converted to short shrub; 50% of conversion for each land cover type within 50-meters of road; tree conversion distributed proportionally between municipal parks and schoolyards; all woodland conversion in parks.

3.4.1 Evaluation of Conversion Scenarios

The quantification methods established by Derkzen et al. (2015) were used to assess UES bundles for the five distinct green infrastructure development scenarios and compare them to the current provision of ES by public green space. The overall changes to runoff retention and recreation were fairly limited for all five scenarios, but carbon storage and air purification differed more substantially (Table 9). Converting all lawn (28.8 ha), excluding lawn within the right-of-way, to woodland would increase air purification by 30.9% from the status quo, removing an estimated 770 kilograms of additional particulate matter, annually, while increasing carbon storage by 126.9% and recreation value by 7.3%. Converting all lawn within 50-meters of roads (14.3 ha) to woodland would increase air purification by 20.5% and carbon storage by 63.2%, while retaining 14.4 hectares of lawn in parks and schoolyards (Table 9). Converting just 50% of all lawn within 50-meters of roads (7.2 ha) to woodland would increase air purification by 10.3%, while converting 50% of lawn within 50-meters of roads to dispersed tree cover would increase air purification by 17.6%, representing the greatest increase in air purification services per hectare of lawn converted. The final scenario involved the conversion of a combined fifteen hectares of lawn to tall shrub (2.5 ha), short shrub (2.5 ha), dispersed tree cover (5 ha), and woodland (5 ha). This scenario would increase air purification by 18.0% and carbon storage by 46.4% (Table 9).

IV. DISCUSSION

In this study, we performed a quantitative analysis of the current delivery of ES at the neighborhood scale, a socio-cultural valuation of ES provided by public green space, and an analysis of potential pathways for increasing the delivery of ES on public green space based on an assessment of the potential impact associated with the increase of specific ES prioritized by stakeholders.

4.1 Public Green Space and Urban Ecosystem Services

Much of the housing in the United States consists of low-density residential development. As of 2010, over 65% of all housing stock in the United States consisted of low-density residential development with fewer than 10 houses per hectare (Romem, 2016). In Eugene, 54.5% of area is zoned for low-density residential development, while in the Friendly Area Neighborhood, 74.5% is zoned for low-density residential development. The median residential tax lot area in the Friendly Area Neighborhood is 0.073 hectares, just below the 0.083 hectare median single-family residential tax lot sold in the U.S (U.S. Census Bureau, n.d.-a). Based on housing density alone, the Friendly Area Neighborhood is fairly representative of urban residential neighborhoods nationwide.

While the Friendly Area Neighborhood median household income is $7,000 and $11,300 below the state and national median household income, respectively (Diebel et al., 2015; U.S. Census Bureau, n.d.-b), access to public green space amenities is adequate. 94.5% of residents are within a 5-minute walking distance from a public park or school yard (Figure 9) and 100% are within a 10-minute walk, which would rank it among the top cities in the United States for park access (The Trust for Public Land, 2018). In the City of Eugene, 17.0% of all area is designated as parks and open space, while 10.3% of all area in the Friendly Area Neighborhood consisted of public green space in parks and schoolyards, which is just above the median of 9.3% for the 100 largest cities in the United States (The Trust for Public Land, 2018). While the Friendly Area Neighborhood's public green space is not proportionate to the city of Eugene as a whole, residents have sufficient access outdoor recreation opportunities, and the area of public green space in the neighborhood exceeds the World Health Organization target for outdoor recreation space per capita (WHO, 2010).

Lawn is the dominant land cover type found on public green space in the Friendly Area Neighborhood (Table 3), which is consistent with other urban areas across the United States and Europe. Of the 142.8 hectares of public land in the Friendly Area Neighborhood, which includes roads, buildings, sidewalks, and green space, 23.5% is covered in lawn, almost identical to the 23% lawn coverage found in a study of the greater Columbus area of Franklin County, Ohio (Robbins & Birkenholtz, 2003). The breakdown of lawn to tree cover in the Friendly Area Neighborhood is similar to that of three cities in Sweden, where lawn covered 22.5% and trees covered 12.8% (Hedblom, Lindberg, Vogel, Wissman, & Ahrné, 2017) compared to 23.5% lawn cover and 17.6% tree cover in the Friendly Area Neighborhood, although neither of these statistics include information about lawn beneath tree canopy cover, which could further increase the disparity. These above comparisons reveal that, while the Friendly Area Neighborhood provides above average access to public green space, available green space is comparable to many of the urban areas that have been researched in this capacity.

Estimating the quantity of UES provided by public green space allows for an evaluation of the co-benefits and tradeoffs of different land cover types (Haase et al., 2012). The quantitative results from this study demonstrate that lawn provides valuable runoff retention services and recreation value, but offers significantly less air purification, carbon storage, and air temperature regulation services compared to trees and shrubs (Table 3). Woodland has the greatest carbon storage capacity and recreation value by area (Table 2), and yet only covers a very small portion of the overall public green space. Analyzing the breakdown of urban green space by land cover type provides insight into current management practices and informs future green infrastructure development.

While the ES that were quantitatively analyzed in this study do not represent the entire suite of ES provided by urban green space, Derkzen et al. (2015) established a method for analyzing ES bundles by land cover type at a scale that was previously unobtainable. This method not only allows us to analyze the current delivery of ES by land cover type at a high resolution, but also allows us to generate future green infrastructure development scenarios, creating a new way to conceptualize green space management.

LiDAR data analysis provided a rapid method for distinguishing land cover by height but failed to differentiate between urban green cover and other, non-green surfaces, such as roads and cars. Combining LiDAR with image analysis to distinguish between land cover types of the same height will increase the accuracy of quantitative results and allow for rapid municipal- and regional-scale analyses. Research that continues to develop methods for UES quantification will allow environmental managers to more accurately assess the ES bundles provided by different land cover types and evaluate the tradeoffs of various public green space planning decisions.

4.2. Stakeholder Perspectives - Resident Surveys

Resident values are critically important to the management, planning, and development of urban public green space (Faehnle, Bäcklund, & Tyrväinen, 2017). Consulting with Friendly Area Neighborhood residents, whereby oral surveys were read aloud, and answers were recorded by the researcher, to better understand their ES priorities for public green space revealed a high perceived value of ES, overall. All but one of the 17 ES assessed in the survey received a mean Likert score greater than 4, or moderately important, and the overall mean score for all the ES combined was 4.44. An analysis of mean Likert scores made it possible to normalize the high average value of all ES, identify trends in resident ES preferences, and compare priorities to surveys conducted among residents from Europe and China.

Resident surveys have been used to identify ES priorities for public green space, and resident ES preferences for urban green space have varied widely by region. Of the 17 ES assessed in this study, privacy and seclusion, noise reduction, community identity, and vegetable production had means that were significant ($p<0.05$) below the overall mean, making them definitively the least valued ES (Table 4). Similarly, noise reduction and community identity were seen as non-priorities among European and Chinese residents (Jim & Chen, 2008; Madureira et al., 2015); however, one survey found that, among gardeners in Barcelona, food supply and social cohesion were among the most important UES, while pollination and biodiversity were relatively unimportant (Camps-

Calvet, Langemeyer, Calvet-Mir, & Gómez-Baggethun, 2016), which contrasts the sentiments of Friendly Area Neighborhood residents.

Seven ES were found to be statistically significant (*p*-values > 0.05) above the overall ES mean, and all but one (outdoor recreation and education) were either supporting or regulating services (Table 4). These results are in contrast to the findings from a survey conducted with residents from four European cities, which found that residents generally valued social and cultural ES over regulating and supporting services (Madureira et al., 2015). In Finland, outdoor recreation was identified by residents as a critical component of urban green space (Tyrväinen et al., 2007), while Chinese residents placed a moderate to low importance on the recreational benefits associated with green space (Jim & Chen, 2008). Although few ES priorities are held in common by residents from Asia, Europe, and the United States, residents from China, Portugal, France, and the Netherlands all identified air purification services as highly important (Derkzen, Marthe L. et al., 2017; Jim & Chen, 2008; Madureira et al., 2015), demonstrating a common interest in access to clean air among residents across continents. These findings indicate that only a few of the ES priorities expressed by Friendly Area Neighborhood residents are consistent with those of residents from Europe and China, and the overall variability of ES preferences among residents from a diversity of cultures demonstrates the value of conducting resident surveys to identify local and regional ES priorities for urban green space.

The ES identified as priorities and non-priorities among Friendly Area Neighborhood residents provide insight into their goals for public green space in the neighborhood. Residents expressed clearly that they are not looking for solitude, serenity, or food production from their neighborhood public spaces. As Eugene is situated within an hour-and-a-half of the Oregon Coast and the Cascade Range, residents are likely willing to make the trip out of the city for peaceful nature experiences. It is interesting, however, that residents showed disdain for urban vegetable gardens on public green space, given that the City of Eugene proudly touts its status as the "#1 city for urban farming", strongly supports urban agriculture through the allotment of community garden space and urban agriculture grants, and notes that Friendly Area Neighborhood residents love to garden (City of Eugene, n.d.-a, n.d.-c). There are several potential rationales for why residents may lack interest in increasing community garden space. Residents may feel that there are already ample opportunities for vegetable gardening as one of the six city-owned community gardens is located in the Friendly Area Neighborhood, and a second community garden in the neighborhood is managed and operated by a group of residents. Because the Friendly Area Neighborhood consists predominantly of single-family detached housing, residents may believe that those who wish to vegetable garden may do so on their private property.

Residents' strong preference towards supporting and regulating services (Table 4) demonstrates the perceived importance of public green space for providing ecological resilience, in addition to human health and well-being. While clean air has obvious human health implications and has been identified as valuable among residents globally, supporting services, such as native species planting and the provision of habitat for birds and pollinators, do not provide direct ES for human health and wellbeing; instead, they represent the underlying ecological requirements that allow for the production of all other ES (Gómez-Baggethun et al., 2013). Prioritizing supporting and habitat services, as well as stormwater pollution mitigation and carbon sequestration, indicates that residents of the Friendly Area Neighborhood have an interest in the preservation and restoration of terrestrial and aquatic ecosystems, even within the city limits. Madison Meadow Park, an 0.8-hectare cooperatively-owned green space in the Friendly neighborhood, is maintained as a refuge for native plants, bird, and butterfly habitat (McWayne, 2013) and offers a microcosm of this sentiment. Although Madison Meadow Park is privately-owned, its existence provides evidence of the environmental bent of the Friendly Area Neighborhood residents. While the ES priorities of Friendly Area Neighborhood residents do not necessarily reflect the values of all Eugene residents, the City of Eugene receives taxpayer money for the continued operation of public green space and therefore has a financial obligation to incorporate the resident ES priorities into the planning and management of these spaces.

Although resident surveys provide insight into the preferences and priorities within a critically important stakeholder group, the survey conducted for this study may have introduced several forms of bias into the results. While a random-sample technique was used to select participants, the sample was not stratified to select proportionately by gender, income, or race, potentially introducing a form of selection bias. In addition, the ES list provided to residents in the survey was not randomly ordered, potentially incorporating response bias. These biases do not necessarily devalue the results from the resident survey but need to be acknowledged as a potential source of error in the data.

4.2.1 Stakeholder Perspectives - Delphi Analysis

The Delphi analysis provided a method to consult with a small group of stakeholders with expertise in environmental management, planning, and public policy, allowing for the consolidation of perspectives regarding ES priorities and green infrastructure development in Eugene as a whole. Over two-thirds of participants identified the importance of providing air and stormwater purification, carbon sequestration, aesthetics and natural beauty, flood reduction, and native plant species on all public green space. Participants acknowledged that air temperature regulation should only be prioritized on right-of-way, while educational opportunities and habitat for birds and pollinators should only be prioritized in parks. In 2016, the City of Eugene Parks and Open Space Division published a report that identified the importance of public parks to serve recreational needs as well as provide terrestrial and freshwater habitat, clean air and water, and air temperature reduction (City of Eugene, 2016). The understanding of public green spaces as critical for providing a diversity of ES pervades not just the Parks and Open Space Division, but also members of the Eugene City Council and the City of Eugene Planning and Development.

While no known Delphi analysis has been conducted, to-date, to assess ES priorities among stakeholders, one study conducted a survey of 600 municipal foresters in the United States and found that approximately 75-90% of respondents thought water quality, beautification, habitat, native biodiversity, and climate regulation through shading were all important considerations for public green space management (Young, 2010). Foresters regarded the importance of carbon sequestration and air pollution reduction as depended on the species type: 80% thought fast growing species were not beneficial for carbon sequestration, while 75% thought slow growing species were (Young, 2010). These findings show a substantial level of agreement between national foresters and the Delphi participants and demonstrate that the concept of ES has reached mainstream environmental managers nationwide.

The remainder of the Delphi surveys were devoted to understanding participants' views on the benefits and problems associated with maintaining lawn on public green space. Participants identified recreational and ease-of-maintenance benefits which were echoed by municipal land managers and politicians in a study conducted in three cities in Sweden (Ignatieva, Eriksson, Eriksson, Berg, & Hedblom, 2017). While most of the problems with lawns that concerned Delphi participants involved the minimal delivery of regulating and supporting services, land managers in Sweden were cognizant of the environmental issues associated with lawn and noted that conventional lawns costed twice as much to maintain as meadow-like lawns, that were mown much less frequently (Ignatieva et al., 2017). This contrasts the perspective from a majority of Delphi participants, who were concerned about the "cost and complexity" associated with the conversion to and maintenance of alternative planting regimes, although the specific components of that complexity were not elaborated upon further (Table 7). To address the problems associated with lawns, over 85% of Delphi participants supported the conversion of some lawn on public green space to alternative planting regimes to increase the delivery of regulating and supporting services, and the only barrier that received over two-thirds consensus was the need to consider sight-lines along right-of-way planting strips. These finding indicate that green space managers and policy-makers in Eugene have a grounded understanding of the values and detriments associated with lawns and are interested in considering green infrastructure development options to increase the delivery of ES on public green space.

4.3 Land Cover Scenario Analysis

Public green space management varies among cities. In the United States, park and open space management is often coordinated by one or more city departments and requires budget approval from a publicly elected city council. Occasionally, cities will contract out park operation and management to third-party organizations, as is the case in Springfield, Oregon. In Eugene, the Parks and Open Space division, within the Public Works Department, is primarily responsible for the operation of public parks. The management of right-of-way planting strips also varies by city, but in Eugene, residents are required to maintain right-of-way planting strips adjacent to their tax lots, although the property is publicly owned. The Stormwater Management and Urban Forestry programs, within the Parks and Open Space division, are directly involved in the planning and maintenance of stormwater facilities and street trees within the right-of-way.

Public green space planning and operations strategies are generally orchestrated by a group of experienced people. In July 2018, the City of Eugene completed a 30-year goals and vision assessment that included consultation with over 12,000 community members (City of Eugene, 2018). In this report, one of the numerous goals is to “further the parks and recreation system’s capacity to serve as critical infrastructure for clean air, clean water, flood control, carbon sequestration, and climate resilience” (City of Eugene, 2018, p. 42); however, no strategies are outlined to increase to delivery of these critical regulating services, and a majority of the attention within the report is given to recreation. While the City of Eugene touts that over 80% of park space is dedicated to natural areas, these large conservation areas that provide a bulk of the ES are concentrated on the outskirts of town (City of Eugene, 2018). In neighborhood and city parks, operations management finds that lawn is neat looking and easy to maintain, and they are in the process of "converting landscape beds of the [19]50-90's into lawn as it has to do with its easier to take care of [sic]" (Delphi participant #8). Although this approach may reduce the burden of maintenance, converting shrub and tree cover to lawn diminishes the delivery of ES prioritized by stakeholders in this study (e.g. air purification). While the City of Eugene has put resources into creating this forward-looking plan and, with a 2018 ballot measure, secured over $50 million in tax bonds and levies to support park operations and development, minimal effort has been put in to generating future green infrastructure scenarios for increasing the delivery of ES.

Stakeholder perspectives may be useful for steering future management directions toward green infrastructure development. Delphi participants acknowledged that lawn provides minimal regulating and supporting services compared to alternative planting regimes, but they identified the cost and complexity of lawn conversion as a barrier to green infrastructure development (Table 7). At the same time, 87.5% of residents stated that they would be willing to financially support green infrastructure development that increases the delivery of ES on public property through tax measures or private donations, providing a potential avenue to address the cost and complexity of land cover conversion (Figure 6). Because the survey only considered residents in one neighborhood, this data may not be reflective of the city as a whole; however, identifying residents' willingness to contribute to public green space development that increases the delivery of ES may be useful to inform future green infrastructure projects in specific neighborhoods and at the city scale.

As the Delphi participants recognized, being able to increase the delivery of ES is reliant on the "quality design and maintenance plans" that are feasible and sustainable long-term. Adaptive design techniques, where small green infrastructure projects are constructed, maintained, and monitored, could provide a model that allows for some experimentation and failure (Ahern et al., 2014). Using resources to identify promising design and maintenance strategies for green infrastructure, other than lawn, may allow for more successful, larger scale planning and implementation.

There are no known studies, to-date, that have conducted independent investigations with multiple stakeholder groups to identify ES priorities and the potential for green infrastructure development. Comparing the results from resident surveys and the Delphi analysis with environmental mangers, policy-makers, and urban planners revealed areas of agreement and disagreement between stakeholder groups, providing a nuanced understanding of the socio-political context surrounding urban green space management. Combining expert and resident ES preferences creates an opportunity to rethink the public green space planning and decision-making status quo.

Overall, there was a significant amount of agreement between the two stakeholder groups. Residents and Delphi participants identified water and air purification, carbon sequestration, native plant species, and habitat for birds and pollinators as the most critical ES for public green spaces to provide (Tables 4 and 6). Among residents and a majority of Delphi participants, outdoor recreation and education were identified as a priority ES, yet most cultural and provisioning services were valued less than regulating and supporting services (Table 4). Many of the ES priorities identified by both stakeholder groups could be increased by converting areas of lawn to alternative land cover types (e.g. dispersed trees, prairie, woodland, and shrubs). Identifying these areas of agreement allows environmental managers and planners to begin considering green infrastructure development pathways to increase ES prioritized residents, environmental managers, policy-makers, and planners alike.

Although there was a substantial level of agreement between stakeholder groups, there were several discrepancies in their ES priorities. Delphi participants placed a high value on the aesthetics and natural beauty of public green space, although residents did not identify this as a priority. While Friendly Area Neighborhood residents were generally unconcerned about the prospect of flooding, two-thirds of Delphi participants identified flood reduction as an important ES provided by public green space. In addition, Delphi participants identified air temperature regulation as an important ES to consider for right-of-way planting strips. It is important to note that Delphi participants were asked to consider ES priorities for public green space at the city scale, while residents were asked to consider just the public green spaces in their neighborhood. Planners, policy-makers and environmental managers need to prioritize certain ES at the city scale (e.g. air quality), while other ES may be more specifically tied to the needs of only a few neighborhoods. Considering ES priorities at both scales may be a practical technique for best management of public green space.

Weighting stakeholder ES priorities for green infrastructure development at both the neighborhood and city scales, based on the biophysical conditions and available space, may be an effective method to address critical environmental and human-health concerns in cities. As one Delphi participant explained, “What drives public agencies such as our Public Works Department is regulatory requirements - meeting the Federal Clean Water Act and our NPDES Permit requirements (e.g. reducing pollution into local waterways, reducing flooding, and improving air quality). Other items are secondary to the basic welfare and safety of the general public [sic]” (Appendix C). This sentiment highlights the importance of air and water pollution mitigation at the city scale, and green infrastructure development in the Friendly Area Neighborhood creates an opportunity to address these issues. While flooding, urban heat islands, and recreation opportunities are important considerations at the city scale, they are not priorities for the Friendly Area Neighborhood, and although carbon sequestration was identified as a priority by both stakeholder groups, quantitative research demonstrates that urban green spaces do not have a significant role in counteracting carbon emissions (Nowak, 1994; Zhao et al., 2016).

The weighting system generated in this study can be used to compare the five green infrastructure development scenarios. All five scenarios would increase the delivery of air and water purification. While the Maximum Air Purification conversion scenario offers the most potential for air purification, carbon sequestration, and recreation value, it would necessitate the conversion of all available lawn, leaving no space for lawn-specific recreational activities and community gathering, which were identified as essential benefits of lawn by Delphi participants (see Table 7). This conversion scenario would not be acceptable to the 93% of Delphi participants who did not want to see all lawn converted to alternative cover types (Table 7). Although Strategic Air Purification 3 is the only scenario that has a recreational tradeoff, reducing recreation value by 2.1%, the value of air purification services outweighs the small decrease in recreation value (Table 9). Of all the conversion scenarios, by converting 7.2 hectares of lawn, within 50-meters of roads, to dispersed tree provides the most efficient return for the ES with the highest informed weight. The Diversity Planting scenario does not maximize the air purification services, nor does it provide the best air purification return per acre of conversion; however, the UES quantification methods used in this study do not allow for an analysis of native species diversity or habitat quality, identified by residents and Delphi respondents as priority ES. Incorporating 15 hectares of dispersed tree cover, woodland, and shrubs provides a potential mechanism for addressing the remaining UES priorities with informed weights of “1” by creating an opportunity for environmental managers and landscape designers to implement restoration projects of varying scales, intended to increase native plant species, bird and pollinator habitat, and aesthetic value. This green infrastructure development scenario has the potential to increase all ES with informed weights greater than “0”, providing the greatest breadth of ES increases.

From this analysis, the Strategic Air Purification 3 and Diversity Planting scenarios illustrate two alternative futures that have the greatest potential to increase the most critical ES identified by stakeholders and ranked by an informed weighting system. This method, combining stakeholder ES priorities with the biophysical context and constraints of the location in question, creates a pathway for environmental managers and planners to assess multiple future green infrastructure development scenarios and reveal the most advantageous course, or courses, of action.

V. CONCLUSION

This study builds upon previous research in the fields of UES and green infrastructure, developing a new method that combines UES quantification with perspectives from residents, environmental managers, city planners, and policy-makers. The quantitative UES analyses performed in this study allow for a relatively easy-to-use approach to identify ES bundles and assess co-benefits and tradeoffs between various land cover types. Combining methods that incorporate perspectives from multiple stakeholder groups creates an opportunity to assess both users' and managers' priorities for public green space. Using an informed weighting process that incorporates stakeholder ES priorities with the biophysical context of the place in question allows for future green infrastructure scenarios to be created and evaluated in comparison to current conditions and the other potential land cover alternatives. Although no specific policy or management guidelines were generated from this study, it provides an approach, used in this case study of the Friendly Area Neighborhood, for advancing public green space policy to meet stakeholder UES priorities and increase the delivery of ES on public green space. With a combination of socio-ecological analyses and quantitative assessment of ES bundles, the method was able to reveal several courses of action that most effectively increase the provision of UES that hold the highest priority among stakeholders.

APPENDIX A

RESIDENT SURVEY

<u>Ecosystem services are benefits that humans receive from nature</u>. For example, trees filter out air pollution that could otherwise damage human lungs. Planting trees also reduces stormwater runoff which can protect houses from flooding damage. Parks and natural areas provide spaces for recreation and aesthetic appreciation. Publicly owned planted areas in the Friendly Neighborhood currently provide multiple environmental benefits to humans but could be designed to increase the provisioning of ecosystem services. In this section, you will indicate how important various ecosystem services are to you in your neighborhood. **For each of the following ecosystem service types, check one box indicating how important on a 1 through 5 scale you consider it to be for your neighborhood, 1 being very unimportant and 5 being very important.**

Please Check One Box Per Row	Very Unimportant (1)	Moderately Unimportant (2)	Neutral (3)	Moderately Important (4)	Very Important (5)	No Opinion/ Don't Know
Reducing pollution into local water bodies	☐	☐	☐	☐	☐	☐
Improving air quality	☐	☐	☐	☐	☐	☐
Providing shade to cool air temperature	☐	☐	☐	☐	☐	☐
Reducing flooding	☐	☐	☐	☐	☐	☐
Providing nutrients to improve soil	☐	☐	☐	☐	☐	☐
Removing atmospheric carbon through the planting of vegetation	☐	☐	☐	☐	☐	☐
Supporting a variety of plants (plant diversity)	☐	☐	☐	☐	☐	☐
Supporting plant species native to Oregon	☐	☐	☐	☐	☐	☐
Providing habitat for pollinating insects	☐	☐	☐	☐	☐	☐
Providing habitat for birds	☐	☐	☐	☐	☐	☐
Providing space for vegetable production	☐	☐	☐	☐	☐	☐
Providing space for fruiting trees and bushes	☐	☐	☐	☐	☐	☐
Providing space for outdoor recreation, exploration, and education	☐	☐	☐	☐	☐	☐
Providing spaces that create community identity	☐	☐	☐	☐	☐	☐
Providing natural beauty	☐	☐	☐	☐	☐	☐
Providing privacy and seclusion	☐	☐	☐	☐	☐	☐
Reducing noise	☐	☐	☐	☐	☐	☐

How important are the following for public green space management:

Please Check One Box Per Row	Very Unimportant (1)	Moderately Unimportant (2)	Neutral (3)	Moderately Important (4)	Very Important (5)	No Opinion/ Don't Know
Low-cost of implementation and maintenance	☐	☐	☐	☐	☐	☐
Easy to maintain	☐	☐	☐	☐	☐	☐
Plantings are neat and orderly	☐	☐	☐	☐	☐	☐

In this section, you will indicate your interest in participating in the planning and planting of public spaces to enhance ecosystem services.

Is there grass/lawn planted on the property where you currently live?

- ☐ Yes
- ☐ No
- ☐ Don't know

Would you be interested in altering the type of plants growing on the property (where you currently live) to increase the provision of ecosystem services? (Select one)

- ☐ Yes, and I would be willing to contribute financially to this type of project
- ☐ Yes, and I would support a tax measure to fund this type of project
- ☐ Yes, but only if I do not have to contribute financially
- ☐ No
- ☐ Don't know

Would you be interested in altering the type of plants growing on public property (in your neighborhood) to increase the provision of ecosystem services? (Select one)

- ☐ Yes, and I would be willing to contribute financially to this type of project
- ☐ Yes, and I would support a tax measure to fund this type of project
- ☐ Yes, but only if I do not have to contribute financially
- ☐ No
- ☐ Don't know

Would you be interested in having your neighborhood parks designed to increase the provision of ecosystem services? (Select one)

- ☐ Yes, and I would be willing to contribute financially to this type of project
- ☐ Yes, and I would support a tax measure to fund this type of project
- ☐ Yes, but only if I do not have to contribute financially
- ☐ No, I'm not interested
- ☐ No opinion

Would you be interested in having right-of-way planting strips (area between the sidewalk and the street) designed to increase the provision of ecosystem services? (Select one)

- ☐ Yes, and I would be willing to contribute financially to this type of project
- ☐ Yes, and I would support a tax measure to fund this type of project
- ☐ Yes, but only if I did not have to contribute financially
- ☐ No, I'm not interested
- ☐ No opinion

How interested would you be in participating in the planning/design process of ecosystem service enhancements in the Friendly neighborhood?

☐ Very Uninterested ☐ Moderately Uninterested ☐ Neutral ☐ Moderately Interested ☐ Very Interested ☐ Don't Know/ No Opinion

How interested would you be in participating in the implementation process of ecosystem service enhancements in the Friendly neighborhood? This could include helping to fundraise, plant, or maintain public projects.

☐ Very Uninterested ☐ Moderately Uninterested ☐ Neutral ☐ Moderately Interested ☐ Very Interested ☐ Don't Know/ No Opinion

How many <u>hours (events) per year</u> might you be willing to provide towards implementing ecosystem services enhancement in the Friendly Neighborhood?

☐ 0 hours ☐ 1 – 4 hours (~1 event) ☐ 4 – 8 hours (~2 events) ☐ 8 – 12 hours (~3 events) ☐ More than 12 hours (More than 3 events)

How long have you lived in the Friendly Neighborhood?

☐ Under 5 years ☐ 5 – 9 years ☐ 10 – 14 years ☐ 15 – 19 years ☐ More than 20 years

What type of resident are you?

☐ Homeowner ☐ Renter ☐ Other: ____________________

APPENDIX B

DELPHI ROUND 1 SURVEY

Thank you so much for your willingness to participate in this research study. Please read the information provided below and then answer the following questions.

The primary objective of this project is to evaluate the potential restoration of ecosystem services achievable by converting lawn on publicly owned land (e.g. right-of-way planting strips, parks, and vacant lots) to alternative planting regimes. A combination of public perception surveys and spatial data collection have been completed to better understand residents' environmental priorities for their public green space and quantify the sizes and distributions of public parcels planted in grass in the Friendly Area Neighborhood. The final phase of this research project involves conducting a Delphi method analysis where professionals from various fields (e.g. city planning, ecology, urban forestry, stormwater management, parks and open space, and landscape architecture) attempt to generate consensus on the benefits and barriers to green infrastructure development in Eugene.

The Delphi method is an iterative survey process in which experts are polled in two or more rounds with the goal of generating consensus on a given topic. After each round, the researchers analyze the data and include the compiled and anonymized responses with the next set of questions. The format and substance of the questions may change based on the responses from the previous round of surveys.

The main goals of this Delphi method analysis are to:

1) Identify areas of consensus around the benefits and barriers to green infrastructure development that increases the provisioning of ecosystem services achievable by converting lawn on publicly owned land to alternative planting regimes.

2) Determine potential strategies to address the most critical barriers to green infrastructure development in Eugene.

Important Definitions:

Ecosystem Services — the benefits humans receive from nature and natural processes

Green Infrastructure — the network of vegetated areas in the urban context that provide ecosystem services

Please read and respond to the following questions from your perspective, providing any relevant expertise you may have from your respective professional field.

What ecosystem services are provided by green infrastructure in cities? Please explain thoroughly.

____

What are the primary benefits of lawn and mown grass planted on public property? Please explain thoroughly.

____

What are the primary concerns with lawn and mown grass planted on public property? Please explain thoroughly.

____

What are the ***benefits*** to converting lawn on public property to alternative planting regimes (e.g. trees, stormwater planters, community vegetable gardens, native plantings, etc.) that increase the provisioning of ecosystem services? Please explain each benefit thoroughly.

____

What are the ***barriers*** to converting lawn on public property to alternative planting regimes that increase the provisioning of ecosystem services? Please explain each barrier thoroughly.

____

What actions are required to overcome these barriers? Please explain thoroughly.

____

Are there any other concerns you have with converting lawn on public property to alternative planting regimes? Please explain each concern thoroughly.

____

Rank the importance of providing the following ecosystem services on public green space from most important (1) to least important (17). You can move each ecosystem service by clicking and dragging to the desired ranking. This list will get pared down after each survey iteration based on responses.

_______ Reducing pollution into local water bodies
_______ Improving air quality
_______ Providing shade/canopy cover
_______ Reducing flooding
_______ Providing nutrients to improve soil
_______ Increasing carbon sequestration
_______ Supporting plant diversity
_______ Supporting native species
_______ Providing pollinator habitat
_______ Providing bird habitat
_______ Providing space for vegetable production
_______ Providing space for fruiting trees and bushes
_______ Providing space for outdoor recreation
_______ Providing space for community gatherings
_______ Providing aesthetic/natural beauty
_______ Providing Privacy and Seclusion
_______ Reducing Noise

Please explain your rationale for your top five ranked ecosystem services in the question above:

____

APPENDIX C

DELPHI ROUND 2 SURVEY

Thanks again for your willingness to participate in the Delphi process. This survey is a refinement of the previous survey and the responses from the first survey have been compiled; the relevant data and a selection of representative responses are provided with each set of new questions. The 15 participants from the first survey represent a diversity of perspectives from the City of Eugene's Public Works, Parks and Open Space, and Planning Departments, as well as representatives from several relevant non-profit organizations and the University of Oregon. You are encouraged to reconsider your responses from the previous survey in light of the collective data.

This will be the final survey, and it should take 25-30 minutes to complete. If you do not have time to complete the survey all at once, you can leave the survey and it will automatically save your responses.

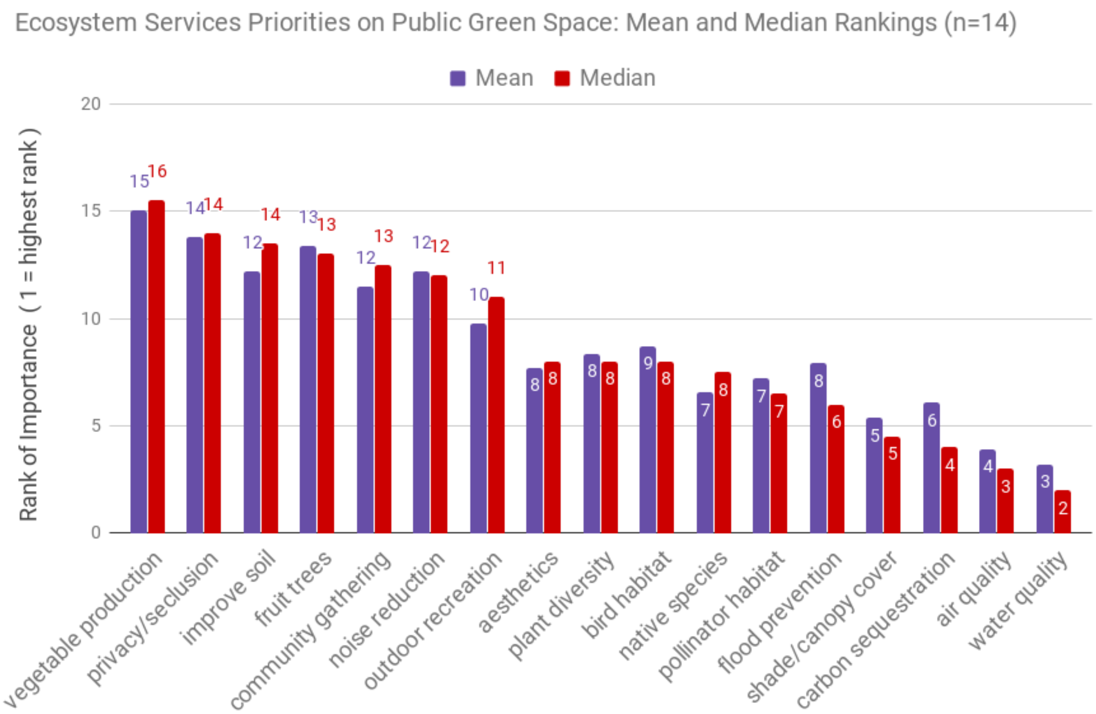
Important Definitions:

Ecosystem Services — the benefits humans receive from nature and natural processes.

Green Infrastructure — the network of vegetated areas in the urban context that provide ecosystem services.

Public Green Space — for the purposes of this study, public green space is defined as planted areas in parks and on the right-of-way planting strips.

Alternative Planting Regimes — plant communities or management plans that differ from mown lawn/turf; these include, but are not limited to, native plantings, landscaped flower and shrub beds, trees/urban forest patches, trees with understory grass/ground cover, vegetable gardens, stormwater planters, rain gardens, vegetated swales, and wetlands.



<u>Ecosystem Service Priorities on Public Green Space: Survey #1 Responses:</u>

1. Water quality, air quality, climate change and biodiversity are the over-arching issues with the most potential to be positively affected in our urban environments.
2. Triple bottom line concepts are reflected in my top 5 items: increasing carbon sequestration, reducing pollution into local water bodies, providing space for outdoor recreation, providing shade/canopy cover, and improving air quality. Providing space for outdoor recreation helps connect people with the benefits of trees and other green infrastructure elements. Canopy coverage percentage has the potential to influence the overall health and well-being of communities. And of course, reducing pollution is self-explanatory.
3. On-site stormwater collection reduces load on city stormwater infrastructure.
4. What drives public agencies such as our Public Works Department is regulatory requirements - meeting the Federal Clean Water Act and our NPDES Permit requirements (e.g. reducing pollution into local waterways, reducing flooding, and improving air quality). Other items are secondary to the basic welfare and safety of the general public.
5. Erosion control benefits the maintenance of natural ecosystems and can help ameliorate damage from natural disasters like wildfires (per California fires in 2017).
6. Pollination opportunities strengthen local biomes.

7. For me, it's all about restoring habitat that's been lost in urban areas to buildings, streets, parking lots, and conventional landscaping (including lawns). It's going to be a much harder sell to get private property owners on board, so let's start with public property.
8. I believe there is currently a deficit in native species, pollinator habitat, carbon sequestration, improved air quality, and reducing pollution into local waterways due to existing and past urban practices. We need to provide opportunities for stop-gaps, then remediation, then propagation to encourage symbiosis between citizens and the natural urban environment.
9. I think traditional water quality services are the most direct benefit to the earth.
10. Providing shade/canopy cover, reducing pollution into local waterway, providing space for outdoor recreation, providing space for community gathering, and providing aesthetic/natural beauty are the benefits most achievable in urban public spaces.
11. The return on investment would seem to be greatest with improving air quality, reducing pollution into local waterways, providing shade/canopy cover, providing aesthetic/natural beauty, and reducing flooding.
12. I support the national pollutant removal and runoff reduction first and then other benefits would follow.
13. Reducing pollution into local waterways, increasing carbon sequestration, reducing flooding, improving air quality, and providing shade/canopy cover have the broadest range of positive impacts to the urban environment.

With these preliminary results in mind, how would you refine these ecosystem services priorities in the management of parks? Select and rank all ecosystem services you consider to be priorities in the management of parks. To select ecosystem services, click and drag from the column on the left into the box labeled 'Priority Ecosystem Services for Parks'. You can then move them into rank order. Several of the ecosystem services that were consistently ranked near the bottom have been removed, and several ecosystem services that were written in have been added.

<u>Priority Ecosystem Services for Parks:</u>

______ Improving Air Quality
______ Reducing Flooding
______ Increasing Carbon Sequestration
______ Providing Habitat
______ Supporting Native Species
______ Supporting Plant Diversity
______ Providing Aesthetic/Natural Beauty

______ Providing Space for Outdoor Recreation
______ Reducing Pollution into Local Water Bodies
______ Providing Shade/Canopy Cover
______ Improving Physical/Mental Health
______ Controlling Erosion
______ Educational Opportunities
______ Other

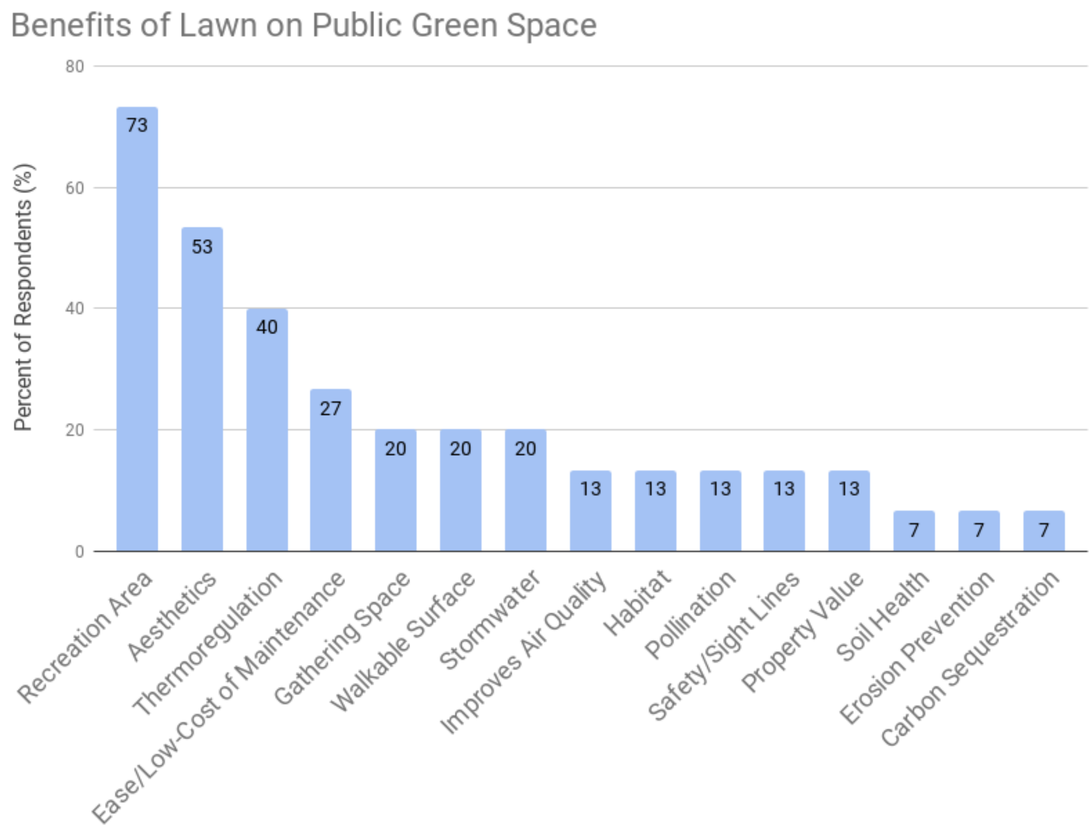
If you selected "Other" above, please define.

With the preliminary results in mind, how would you refine these ecosystem services priorities in the management of right-of-way planting strips? Select and rank all ecosystem services you consider to be priorities in the management of right-of-way planting strips. To select ecosystem services, click and drag from the column on the left into the box labeled 'Priority Ecosystem Services for Right-of-Way Planting Strips'. You can then move them into rank order.

Priority Ecosystem Services for Right-of-Way Planting Strips:

______ Improving Air Quality
______ Reducing Flooding
______ Increasing Carbon Sequestration
______ Providing Habitat
______ Supporting Native Species
______ Supporting Plant Diversity
______ Providing Aesthetic/Natural Beauty
______ Providing Space for Outdoor Recreation
______ Reducing Pollution into Local Water Bodies
______ Providing Shade/Canopy Cover
______ Improving Physical/Mental Health
______ Controlling Erosion
______ Educational Opportunities
______ Other

If you selected "Other" above, please define.



Benefits of Lawn on Public Space: Survey #1 Responses

1. Who doesn't like a manicured lawn? It looks clean and inviting as opposed to dead, unkempt and overgrown.
2. There are different types of uses for turf lawns in City of Eugene: 1) sports play for soccer, softball, and football 2) General use for tossing around a Frisbee and sun bathing 3) Special community events like at Alton Baker Park where events rent the space to have activities.
3. Popular sentiment aside, turf is a simple treatment that is easy to maintain and is a walkable, playable multipurpose surface that facilitates many activities.
4. Turf and mown grass provide some minimal ecosystem services in terms of thermoregulation, infiltration, and sometimes pollinator habitat. However, the main benefit of lawn is for some open space recreation like sports fields.
5. Lawn establishes living ground cover that prevents soil erosion and provides temperature reduction to offset paved surfaces and provides aesthetic value.
6. Ornamental lawn adds to property value.

7. The primary benefits are for recreation, or for people who see mowed lawns as "appropriate landscaping in an urban setting." It's something that Americans are socialized to appreciate.
8. It indicates that the people caring for these lawns--public employees--are doing their jobs by keeping nature under control.
9. Lawn allows citizens to be involved in passive recreation activities with low sight lines (safety).
10. Reduced maintenance cost versus intensely managed landscapes.

With the preliminary results in mind, identify the benefits of lawn planted in parks. Select and rank any items from the column on the left you consider to be benefits of lawn in parks. To select benefits, click and drag from the column on the left into the box labeled 'Benefits of Lawn in Parks'. You can then move them into rank order.

Benefits of Lawn in Parks:

______ Space for Recreation
______ Aesthetics
______ Thermoregulation/Reducing Heat Island Effect
______ Ease of Maintenance
______ Low Cost of Maintenance
______ Space for Gathering
______ Walkable Surface
______ Stormwater Retention
______ Stormwater Pollutant Removal
______ Improved Air Quality
______ Habitat
______ Pollination
______ Safety/Sight Lines
______ Property Value
______ Soil Health
______ Erosion Prevention
______ Carbon Sequestration
______ Other

If you selected "Other" above, please define.

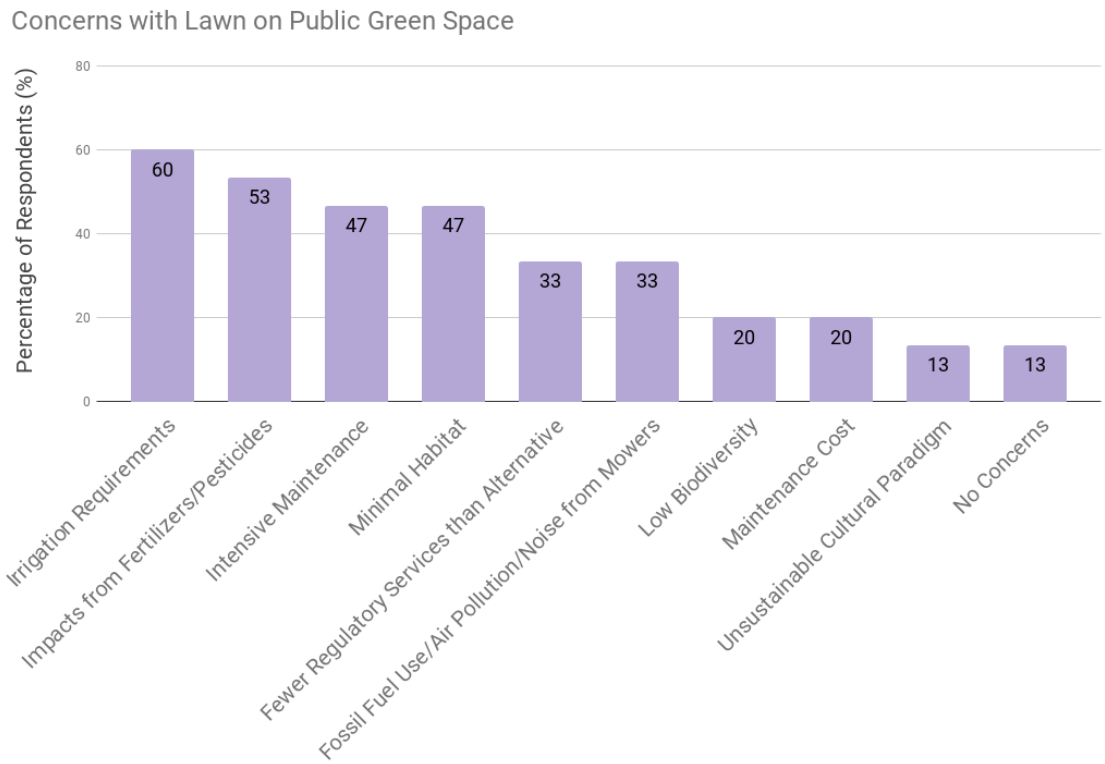
____

With the preliminary results in mind, identify the benefits of lawn on right-of-way planting strips. Select and rank any items from the column on the left you consider to be benefits of lawn on right-of-way planting strips. To select benefits, click and drag from the column on the left into the box labeled 'Benefits of Lawn on Right-of-Way Planting Strips'. You can then move them into rank order.

Benefits of Lawn on Right-of-Way Planting Strips:

_______ Space for Recreation
_______ Aesthetics
_______ Thermoregulation/Reducing Heat Island Effect
_______ Ease of Maintenance
_______ Low Cost of Maintenance
_______ Space for Gathering
_______ Walkable Surface
_______ Stormwater Retention
_______ Stormwater Pollutant Removal
_______ Improved Air Quality
_______ Habitat
_______ Pollination
_______ Safety/Sight Lines
_______ Property Value
_______ Soil Health
_______ Erosion Prevention
_______ Carbon Sequestration
_______ Other

If you selected "Other" above, please define.



<u>Concerns with Lawn on Public Space: Survey #1 Responses</u>

1. The main concerns with lawns on public property relate to high fossil fuel use for maintenance (mowing), high water usage (irrigation), maintenance requirements (staff time), storm water quality concerns (runoff of fertilizer and herbicides), and the perpetuation of unsustainable cultural expectations.
2. Lawns and mowed grass are enormously expensive to maintain—water, possibly fertilizer and pesticides, maintenance of the irrigation system, fossil fuels to mow and to transport machinery from one park to the next, etc.
3. The cost incurred by eliminating whatever natural habitat—grassland, savanna, woodland—that would otherwise have existed on that site.
4. Even though I grew up with an appreciation for lawns (being an American), I now see them mostly as "lost opportunities" where a much more nature-friendly landscape could be occupying that site. Yes, I suppose we need playing fields and places to sit in the sunshine and read, but we've gone way, way overboard. It's just that, in this culture--and of course in many others around the world now--we grow up learning how to take care of a lawn, but we never learn how to design, plant, and take care of the many more nature-friendly options.
5. Lawn doesn't have the highest level of habitat value or water and air quality benefits.

6. If public lands were to turn off irrigated lawns, the fields crack, impacting playability and can create hazards to all the users.
7. Pesticides are used to maintain a monocrop and remove broad-leaved plants from lawn reducing wildlife value above and below ground. Over fertilization causes nutrients to enter the streams through storm events (pesticides too).
8. Lawn has less to offer in terms of both wildlife value and heat island reduction than other, more complex plantings, and is shown to have high sediment runoff.
9. Noise and air pollution from lawn mowers and leaf blowers.
10. Maintenance costs associated with mowing, fertilizing and watering.
11. Lack of plant diversity and wildlife habitat.

With the preliminary results in mind, identify the concerns with lawn planted in parks. Select and rank any items from the column on the left you consider to be concerns associated with lawn planted in parks. To select concerns, click and drag from the column on the left into the box labeled 'Concerns Regarding Lawn in Parks'. You can then move them into rank order.

Concerns Regarding Lawn in Parks:

______ Irrigation Requirements
______ Impacts from Fertilizers/Pesticides/Herbicides
______ Intensive Maintenance
______ Minimal Habitat
______ Provides Fewer Regulatory Services than Alternative Planting Regimes **
______ Fossil Fuel Use/Air Pollution/Noise from Mowers
______ Low Biodiversity
______ Maintenance Cost
______ Unsustainable Cultural Paradigm
______ None
______ Other

** Regulatory services include carbon sequestration, urban heat island mitigation, improved air quality, stormwater runoff reduction and filtration, and erosion prevention.

If you selected "Other" above, please define.

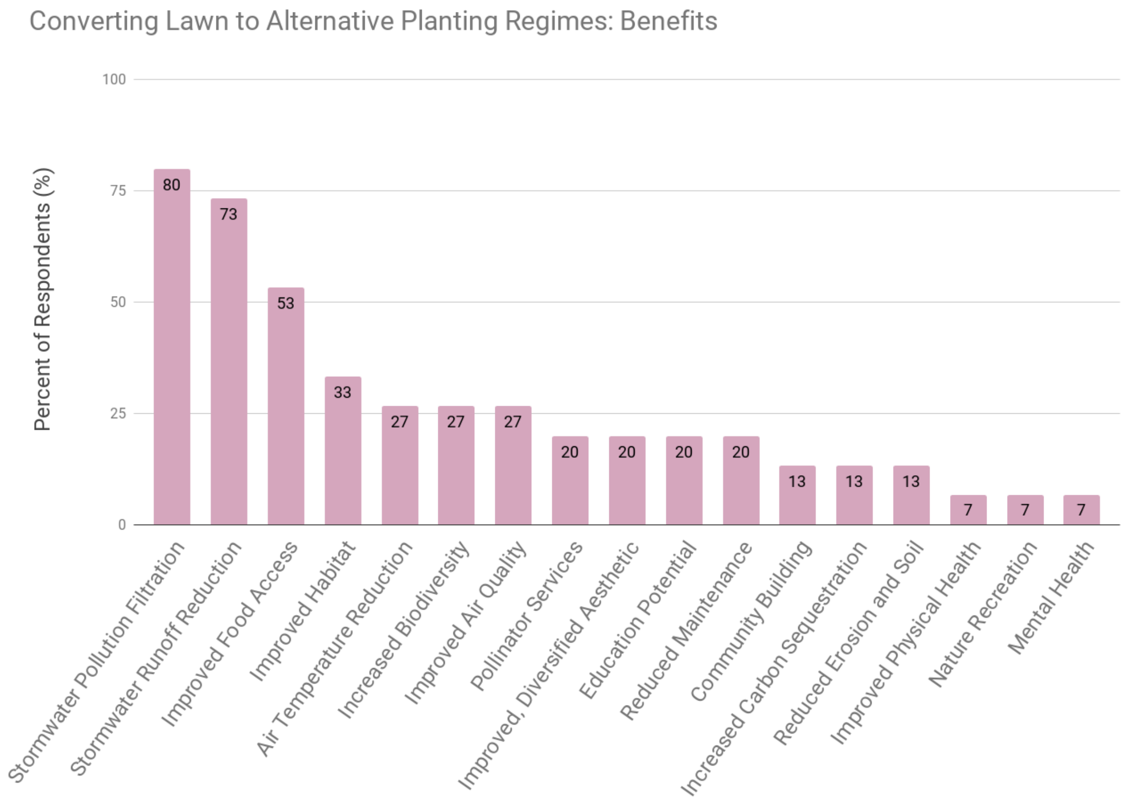
With the preliminary results in mind, identify the concerns with lawn planted on right-of-way planting strips. Select and rank any items from the column on the left you consider to be concerns associated with lawn planted on right-of-way planting strips. To select concerns, click and drag from the column on the left into the box labeled 'Concerns Regarding Lawn on Right-of-Way Planting Strips'. You can then move them into rank order.

<u>Concerns Regarding Lawn on Right-of-Way Planting Strips:</u>

______ Irrigation Requirements
______ Impacts from Fertilizers/Pesticides/Herbicides
______ Intensive Maintenance
______ Minimal Habitat
______ Provides Fewer Regulatory Services than Alternative Planting Regimes **
______ Fossil Fuel Use/Air Pollution/Noise from Mowers
______ Low Biodiversity
______ Maintenance Cost
______ Unsustainable Cultural Paradigm
______ None
______ Other

** Regulatory services include carbon sequestration, urban heat island mitigation, improved air quality, stormwater runoff reduction and filtration, and erosion prevention.

If you selected "Other" above, please define.



Benefits of Converting Lawn to Alternative Planting Regimes: Survey #1 Responses

1. I don't believe that converting all lawn on public property would be a benefit, because lawn does have benefits of its own. However, the conversion of lawn in targeted areas could be beneficial given the right circumstances. For instance, lawns in medians are problematic because they require regular mowing which can put employees at risk as they work in the right of way.
2. Conversion of lawns in medians to trees (even set in permeable pavement) can reduce risk to staff and promote ecosystem services, including carbon sequestration, stormwater capture and filtration, reducing temperatures, creating continuous canopy for habitat.
3. Some lawn in parks could be transitioned (although I wouldn't support all lawn going away). A great example of an area that was transitioned from lawn to native plants is in Skinner Butte Park, just east of Lamb Cottage. This area is very wet, and the mowers get bogged down and leave terrible ruts every year when mowing in the spring. The City piloted a project to convert to native plants and have generally found success. Some members of the public complained that it looked messy and "why weren't we mowing and maintaining that area?". The City responded by incorporating rustic fencing to delineate it as a unique area and

interpretive signage. The amount of biodiversity and habitat in that area is strikingly different than in the adjacent lawn areas.

4. The benefits of converting public lawns to forests include: less frequent/reduced maintenance, increased carbon sequestration, improved soil formation/health, improved stormwater management.
5. Stormwater planters/rain gardens/bioswales can help to improve aesthetics, water quality and quantity.
6. Community gardens/orchards can help to provide food and increase public awareness about food security.
7. Native plantings can help reduce energy inputs, maximize wildlife/pollinator habitat and contribute to ecosystem integrity.
8. There are enormous benefits to almost anything but lawns (well, parking lots and buildings and streets are even worse than lawns, but not by much). Knowing what we, as a society, now know about "ecosystem services" and the benefits of more nature-friendly landscaping, it's especially important for public entities to "show the way" to the rest of society, by implementing more nature-friendly practices in everything they do. In a word, it's about education. By changing our practices on public property, we're "showing the way" to the rest of society and demonstrating that this is not just okay, but is much preferred to the status quo for reasons A, B, C, etc.
9. Cleaner and cooler water and air, less energy needed by neighboring buildings to cool in the summer, closer connection to nature for those who spend more time outside because of the inviting, engaging landscape, more exercise for the same people, local food benefits including addressing food scarcity issues, and connecting people to their food source.
10. Benefits of conversion include increased species diversity (many plant genera), improved water quality (filtering through roots, reduction of polluting fertilizers), pollinator attraction (many kinds of blooms), aesthetics (blooming and foliage), educational opportunities (all around), community building, increased habitat (diversity of type, size, shape and bloom), shade, food production (community gardens).
11. Community vegetable gardens provide social and economic benefits, and less of the ecological benefits.
12. Benefits may include reduction of the urban heat island effect and additional storm water runoff reduction.

With the preliminary results in mind, identify the benefits of converting lawn planted in parks to alternative planting regimes. Select and rank any items from the column on the left you consider to be benefits associated with converting lawn in parks to alternative planting regimes. To select benefits, click and drag from the column on the left into the box labeled 'Benefits of Converting Lawn in Parks'. You can then move them into rank order.

Benefits of Converting Lawn in Parks:

_______ Increased Stormwater Pollution Filtration
_______ Stormwater Runoff Reduction
_______ Improved Food Access
_______ Improved Habitat
_______ Air Temperature Reduction
_______ Increased Biodiversity
_______ Improved Air Quality
_______ Pollinator Services
_______ Improved/Diversified Aesthetics
_______ Education Potential
_______ Reduced Maintenance Inputs
_______ Reduced Maintenance Cost
_______ Community Building
_______ Increased Carbon Sequestration
_______ Reduced Erosion
_______ Increased Soil Formation
_______ Improved Physical Health
_______ Increased Nature Recreation Opportunities
_______ Improved Mental Health
_______ None
_______ Other

If you selected "Other" above, please define.

____

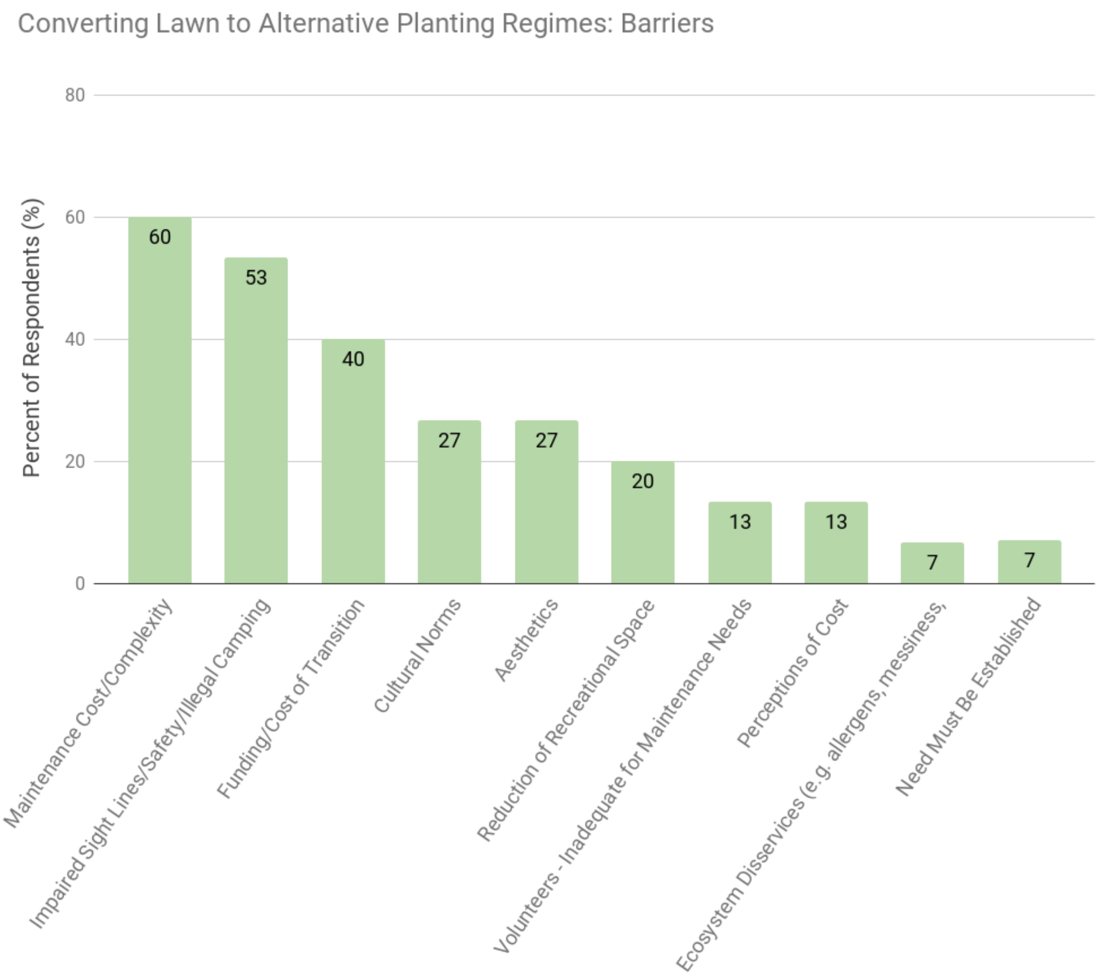
With the preliminary results in mind, identify the benefits of converting lawn planted on right-of-way planting strips to alternative planting regimes. Select and rank any items from the column on the left you consider to be benefits of converting lawn on right-of-way planting strips to alternative planting regimes. To select benefits, click and drag from the column on the left into the box labeled 'Benefits of Converting Lawn on Right-of-Way Planting Strips'. You can then move them into rank order.

Benefits of Converting Lawn on Right-of-Way Planting Strips:

_______ Increased Stormwater Pollution Filtration
_______ Stormwater Runoff Reduction
_______ Improved Food Access
_______ Improved Habitat
_______ Air Temperature Reduction
_______ Increased Biodiversity
_______ Improved Air Quality
_______ Pollinator Services
_______ Improved/Diversified Aesthetics
_______ Education Potential
_______ Reduced Maintenance Inputs
_______ Reduced Maintenance Cost
_______ Community Building
_______ Increased Carbon Sequestration
_______ Reduced Erosion
_______ Increased Soil Formation
_______ Improved Physical Health
_______ Increased Nature Recreation Opportunities
_______ Improved Mental Health
_______ None
_______ Other

If you selected "Other" above, please define.

____



Barriers to Converting Lawn to Alternative Planting Regimes: Survey #1 Responses

1. From a maintenance perspective, large expanses of lawn are relatively easy to maintain. Our maintenance regimes are suited to mechanized mowing as opposed to landscape bed care which tend to require hand weeding. The City uses an Integrated Pest Management approach to pesticides and minimizes use altogether whenever possible. This means that a lot of handwork is needed wherever landscape beds or stormwater facilities exist and this limits the amount of these types of landscapes that we can support.
2. Volunteers are often suggested to fill in the maintenance gaps, and they are definitely used, but there is a limit to the number of volunteers and their long-term commitment to any particular project. When the volunteers move away or move on to a different interest, the maintenance falls back to the city.

3. Regarding community gardens, these must be maintained and managed well. Individuals must be responsible to avoid pest infestations and weed seeds contaminating neighbor plots.
4. From a public safety perspective, having visible sight lines through public spaces is important for law enforcement and the public to be able to see their surroundings. Lawn is well suited to this, while more natural areas can offer hiding spots.
5. I believe there are concerns about maintenance of new facilities and making mowing harder and more time consuming if trees and other facilities like swales are incorporated. There's also limits on funding to complete conversion projects.
6. Some of the main barriers to the conversion of public lawns to alternative planting regimes include: perceptions that alternative landscapes are unkempt/unattractive/not conducive to public use or enjoyment; the belief that alternative planting regimes require more maintenance than lawns; and the belief that alternative plantings encourage illegal camping.
7. The major barrier is aesthetic. The same people who have no problem whatsoever with grasses waving in the wind, or unmowed road shoulders, or branches and leaves lying on the ground when they visit national parks and other "nature preserves," find these things unacceptable in urban areas. We have two heads: our rural, nature-friendly heads, and our urban nature-unfriendly heads. Yeah, we accept some wild areas or parks within the urban zone, but for the most part, we expect landscapes to appear more "controlled" and "tidy."
8. Lack of staff resources to provide necessary outreach to adjacent property owners.
9. Access to irrigation necessary for plant establishment.
10. Limited budget for associated costs of removing turf, modifying irrigation systems, soil amendments and plants + labor for installation and plant establishment.
11. People don't like change.

With the preliminary results in mind, identify the barriers to converting lawn in parks to alternative planting regimes. Select and rank any items from the column on the left you consider to be barriers to converting lawn in parks to alternative planting regimes. To select barriers, click and drag from the column on the left into the box labeled 'Barriers to Converting Lawn in Parks'. You can then move them into rank order.

<u>Barriers to Converting Lawn in Parks:</u>

______ Cost of Maintenance
______ Increased maintenance Time/Complexity
______ Cost of Implementation/Transition

_______ Impaired Safety/Sight Lines
_______ Increased Opportunities for Illegal Camping
_______ Aesthetics
_______ Reduction of Recreational Space
_______ Volunteers Inadequate to Meet Increased Maintenance Needs
_______ Perceptions of Increased Cost
_______ Increased Ecosystem Disservices (e.g. allergens and messiness)
_______ Cultural Norm
_______ Need Must Be Established
_______ None
_______ Other

If you selected "Other" above, please define.

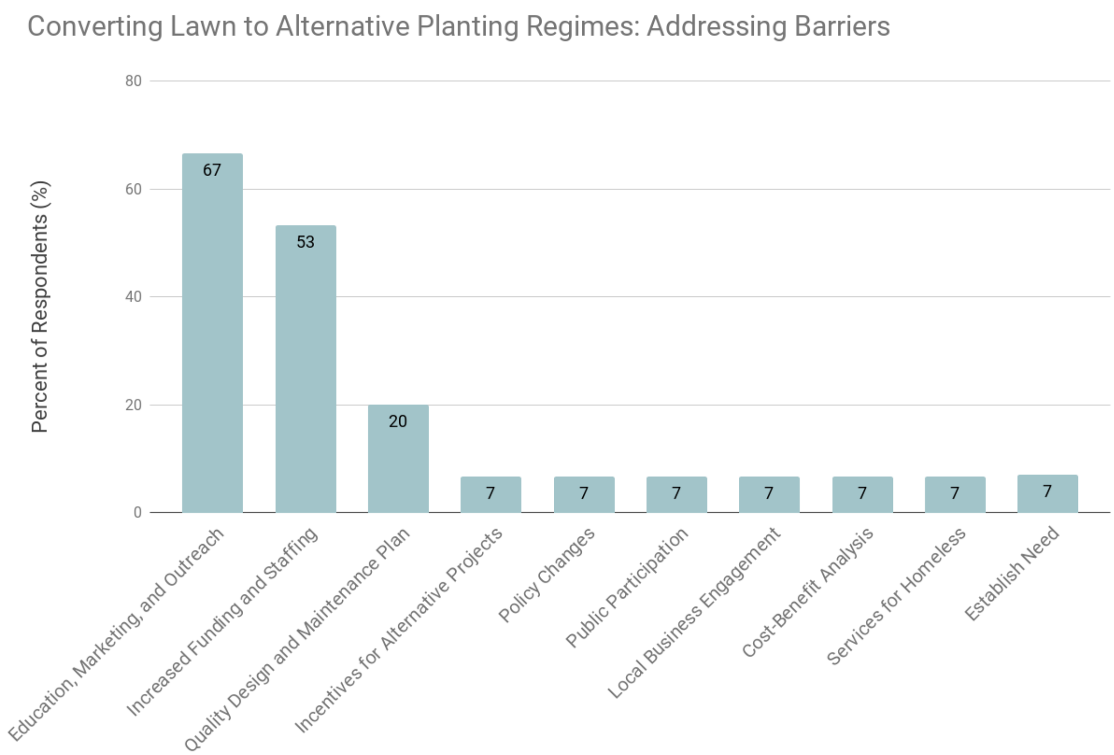
____

With the preliminary results in mind, identify the barriers to converting lawn on right-of-way planting strips to alternative planting regimes. Select and rank any items from the column on the left you consider to be barriers to converting lawn on right-of-way planting strips to alternative planting regimes. To select barriers, click and drag from the column on the left into the box labeled 'Barriers to Converting Lawn on Right-of-Way Planting Strips'. You can then move them into rank order.

<u>Barriers to Converting Lawn on Right-of-Way Planting Strips:</u>

_______ Cost of Maintenance
_______ Increased maintenance Time/Complexity
_______ Cost of Implementation/Transition
_______ Impaired Safety/Sight Lines
_______ Increased Opportunities for Illegal Camping
_______ Aesthetics
_______ Reduction of Recreational Space
_______ Volunteers Inadequate to Meet Increased Maintenance Needs
_______ Perceptions of Increased Cost
_______ Increased Ecosystem Disservices (e.g. allergens and messiness)
_______ Cultural Norm
_______ Need Must Be Established
_______ None
_______ Other

If you selected "Other" above, please define.



Addressing the Barriers to the Conversion of Lawn to Alternative Planting Regimes: Survey #1 Responses

1. Long-term, sustainable funding to support the ongoing maintenance and operations of alternative landscapes is needed.
2. There are any number of management scenarios that could also work (long-term adoption or lease to other agencies or organizations), but the funding will be an issue regardless of who is managing the facilities.
3. Come up with a plant community that is low maintenance and attempts to exclude weeds.
4. First a need to do so would have to be established. We are currently using public lands to treat stormwater under current federal regulations.
5. Coordinated outreach and marketing campaign to involve the public participation.
6. Budgeting for capital expenses associated with converting lawn areas to alternative uses.
7. Policy changes within city departments to align with alternative uses.

8. Good examples on both city and private properties, including signage.
9. Education! Teaching by example and erecting tasteful signs that explain why this landscape looks different from what people are accustomed to and listing the many "ecosystem services" it provides. Everyone is "an environmentalist" to some degree; but most simply don't understand that what we do on public property (and of course in our private yards, as well), is very, very nature-unfriendly, when it could be just the opposite. I truly think that, given appropriate information, and tips on how to convert, say, lawn to "meadow," most people would get on-board with the new program.
10. Public education and sharing information about experiments/case studies will help to overcome these barriers.
11. Incentivizing alternative projects will help.
12. Sustainable and dedicated funding for public lands.
13. Analyze associated costs.
14. Spend the money upfront for initial establishment to prevent weed infestations.
15. Services to prevent homelessness and drug abuse.

With the preliminary results in mind, identify the potential strategies for addressing barriers to converting lawn in parks to alternative planting regimes. Select and rank any items from the column on the left you consider to be suitable strategies for addressing barriers to converting lawn in parks to alternative planting regimes. To select strategies, click and drag from the column on the left into the box labeled 'Strategies for Addressing Barriers to Converting Lawn in Parks'. You can then move them into rank order.

Strategies for Addressing Barriers to Converting Lawn in Parks:

______ Education, Marketing, and Outreach
______ Increased Funding
______ Increased Staffing
______ Identify Priority Locations
______ Quality Design and Maintenance Plans
______ Incentives for Alternative Planting Regimes
______ Policy Changes
______ Public Participation
______ Local Business Engagement
______ Cost-Benefit Analysis
______ Other

If you selected "Other" above, please define.

With the preliminary results in mind, identify the potential strategies for addressing barriers to converting lawn on right-of-way planting strips to alternative planting regimes. Select and rank any items from the column on the left you consider to be suitable strategies for addressing barriers to converting lawn on right-of-way planting strips to alternative planting regimes. To select strategies, click and drag from the column on the left into the box labeled 'Strategies for Addressing Barriers to Converting Lawn on Right-of-Way Planting Strips'. You can then move them into rank order.

Strategies for Addressing Barriers to Converting Lawn on Right-of-Way Planting Strips:

______ Education, Marketing, and Outreach
______ Increased Funding
______ Increased Staffing
______ Identify Priority Locations
______ Quality Design and Maintenance Plans
______ Incentives for Alternative Planting Regimes
______ Policy Changes
______ Public Participation
______ Local Business Engagement
______ Cost-Benefit Analysis
______ Other

If you selected "Other" above, please define.

____

Do you support the transition of lawn in parks to alternative planting regimes?

○ Yes, I want to see all lawn in parks converted to alternative planting regimes.

○ Yes, but I do not want all lawn in parks converted to alternative planting regimes.

○ No, I do not support the conversion of any lawn in parks to alternative planting regimes.

Do you support the transition of lawn on right-of-way planting strips to alternative planting regimes?

○ Yes, I want to see all lawn on right-of-way planting strips converted to alternative planting regimes.

○ Yes, but I do not want all lawn on right-of-way planting strips converted to alternative planting regimes.

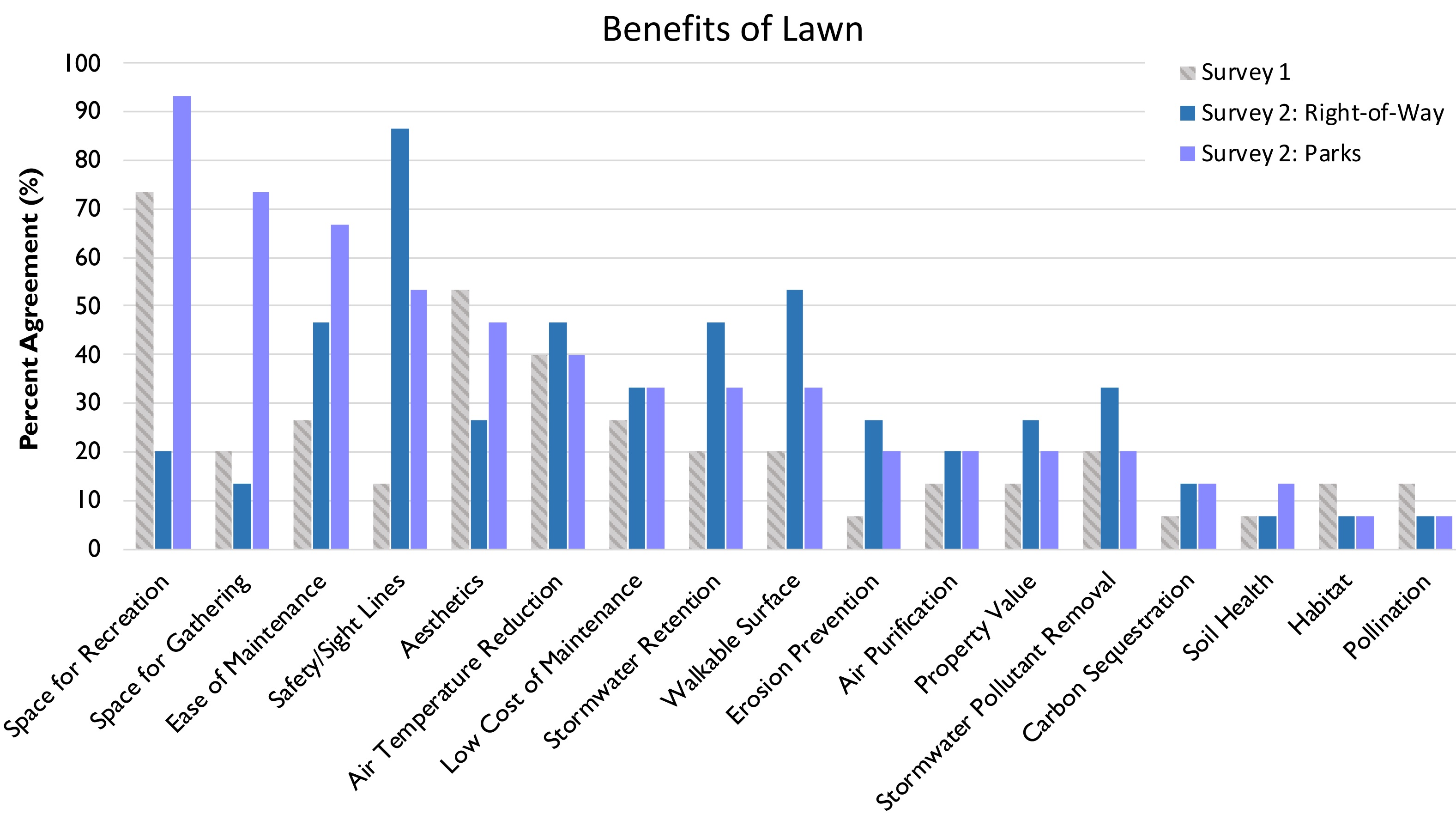
○ No, I do not support the conversion of any lawn on right-of-way planting strips to alternative planting regimes.

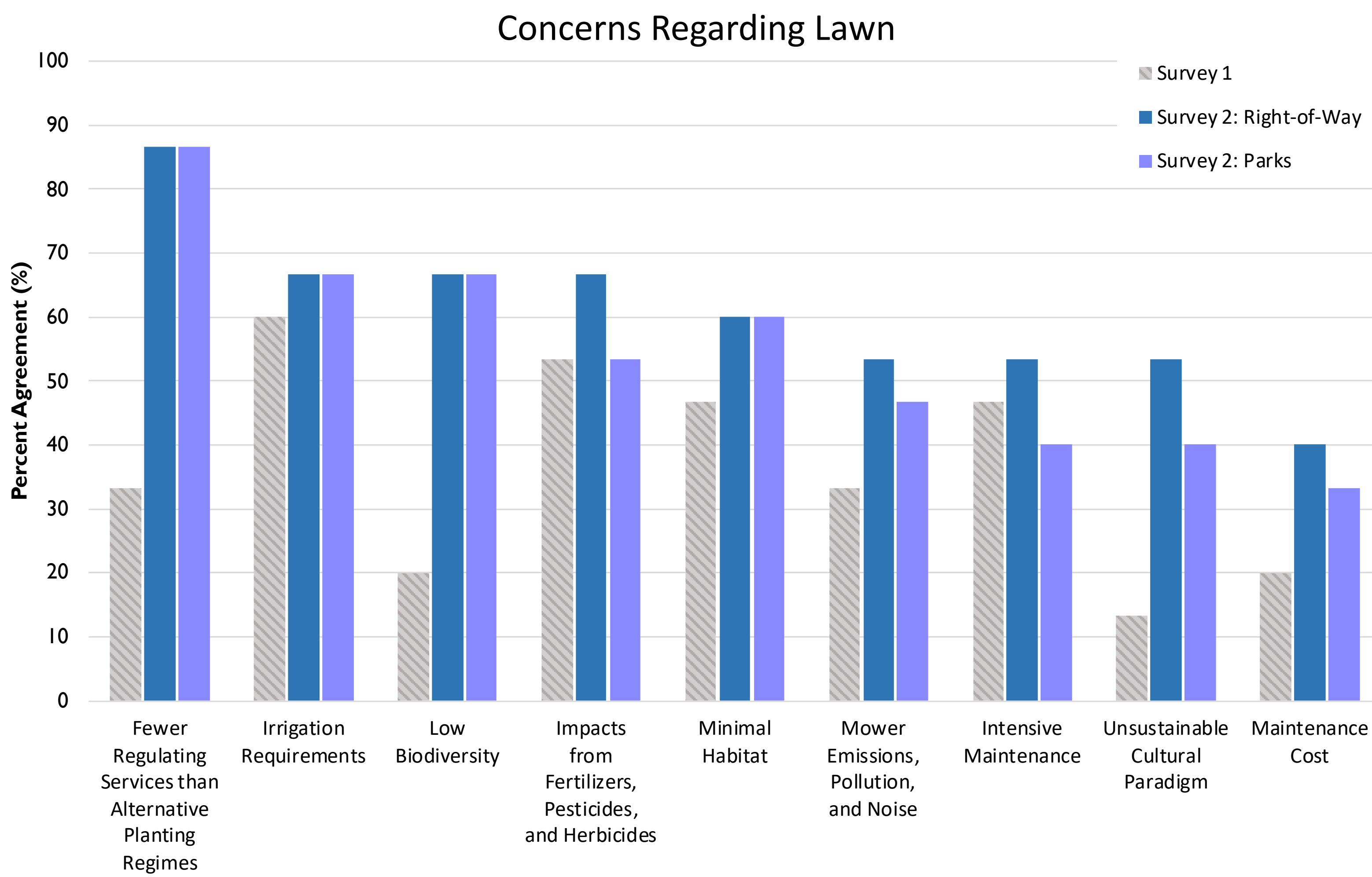
Do you have any additional comments, questions, or concerns?

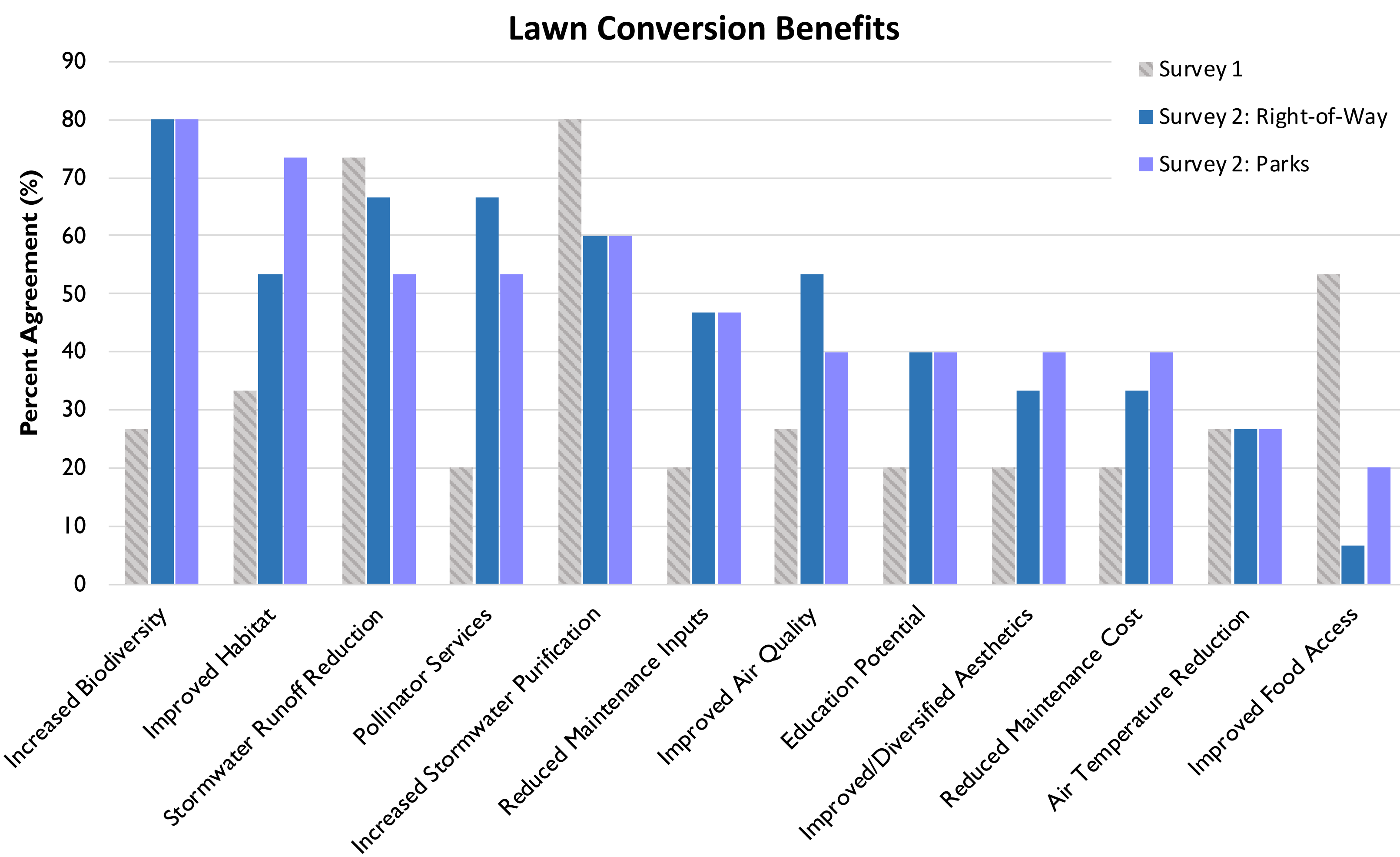
____

APPENDIX D

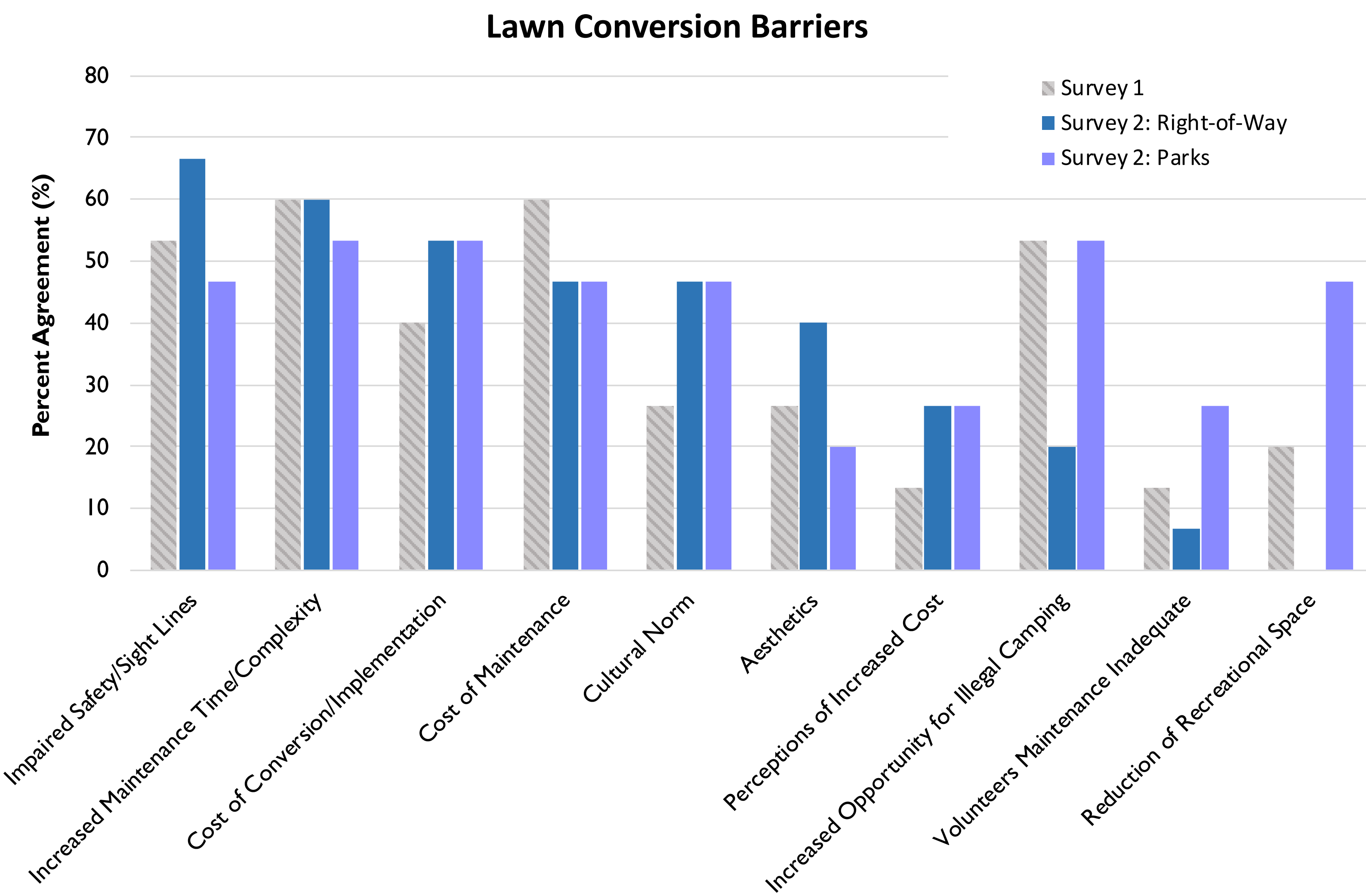
DELPHI ROUND 2 SURVEY RESULTS

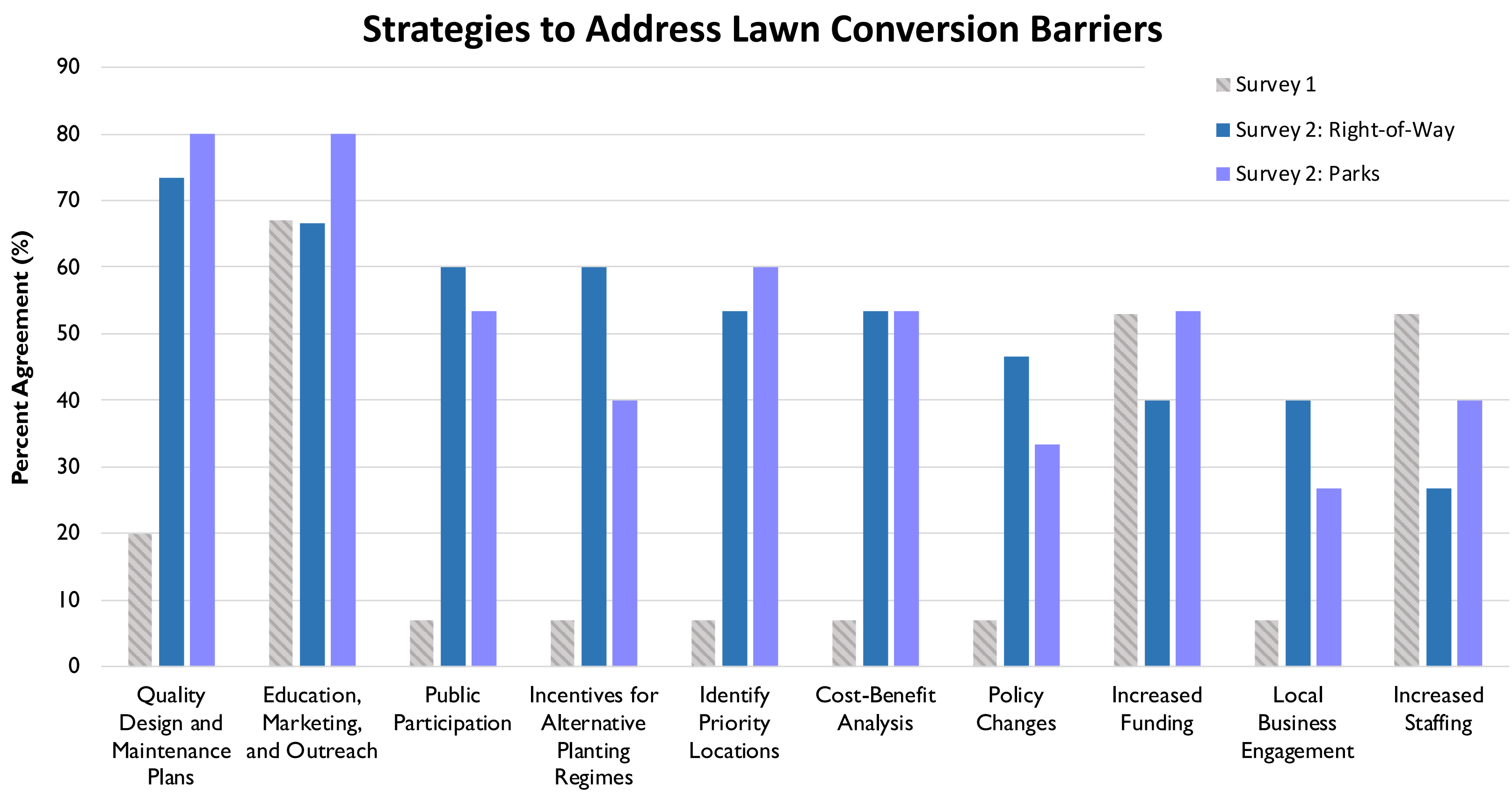



Concerns Regarding Lawn
Percent Agreement (%)
0
10
20
30
40
50
60
70
80
90
100
Survey 1
Survey 2: Right-of-Way
Survey 2: Parks
Fewer Regulating Services than Alternative Planting Regimes
Irrigation Requirements
Low Biodiversity
Impacts from Fertilizers, Pesticides, and Herbicides
Minimal Habitat
Mower Emissions, Pollution, and Noise
Intensive Maintenance
Unsustainable Cultural Paradigm
Maintenance Cost



Lawn Conversion Benefits
Survey 1
Survey 2: Right-of-Way
Survey 2: Parks
Percent Agreement (%)
0
10
20
30
40
50
60
70
80
90
Increased Biodiversity
Improved Habitat
Stormwater Runoff Reduction
Pollinator Services
Increased Stormwater Purification
Reduced Maintenance Inputs
Improved Air Quality
Education Potential
Improved/Diversified Aesthetics
Reduced Maintenance Cost
Air Temperature Reduction
Improved Food Access


Lawn Conversion Barriers
Percent Agreement (%)
80
70
60
50
40
30
20
10
0
Survey 1
Survey 2: Right-of-Way
Survey 2: Parks
Impaired Safety/Sight Lines
Increased Maintenance Time/Complexity
Cost of Conversion/Implementation
Cost of Maintenance
Cultural Norm
Aesthetics
Perceptions of Increased Cost
Increased Opportunity for Illegal Camping
Volunteers Maintenance Inadequate
Reduction of Recreational Space


Strategies to Address Lawn Conversion Barriers
Percent Agreement (%)
90
80
70
60
50
40
30
20
10
0
Survey 1
Survey 2: Right-of-Way
Survey 2: Parks
Quality Design and Maintenance Plans
Education, Marketing, and Outreach
Public Participation
Incentives for Alternative Planting Regimes
Identify Priority Locations
Cost-Benefit Analysis
Policy Changes
Increased Funding
Local Business Engagement
Increased Staffing

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