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Analysis of Impacts to Ecosystem Services of Tree Replacement - Recommendations for Broadway Arboretum Phase One

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Summary of Findings & Recommendations

- Based on the criteria of starting replacements with the existing trees that are in poor overall health/condition & clustering Phase One trees to enhance project visibility, we recommend replacing the six Norway Maples in front of Cramer Hall on the west side of Broadway Ave (between Montgomery St. and Mill St.). The seven Norway Maples on both sides of Broadway between Harrison and Montgomery Streets also met these criteria but we have not yet completed a replacement analysis for them.
- Analysis of evergreen and fast-growing broadleaf species did not show significant ecosystem benefits compared to the mixed tree species of the Broadway Arboretum Plan over a 10 year period. Fast-growing broadleaf trees did contribute to slightly higher rates of avoided runoff and tree coverage after 10 years. However, the results were not significant enough to recommend a change to the Broadway Arboretum Planting Plan.

Introduction & Project Objective

The Broadway Arboretum Project is a coordinated effort between the Campus Planning Office (CPO), Campus Sustainability Office (CSO), and the Facilities and Property Management team (FPM) that seeks to increase diversity and resilience of PSU's urban forest by replacing the existing trees lining Broadway Ave. between I-405 and SW Market Street (currently consisting of almost entirely a single variety, Norway Maple) with a variety of trees that showcase those currently approved by the City for street tree planting while also providing a testing ground for additional varieties that might by resilient to the challenges of growing and surviving in Portland's urban environment.

Phase One of the Broadway Arboretum Project is planned to involve the replacement of 5 - 15 trees. The overall objective of this project was to make planting recommendations (replacement sites and tree varieties) for these 5 - 15 trees based on an analysis of the ecosystem services they are likely to provide over the first 10 years following replacement.

Evaluations of the multiple social, economic, and environmental benefits of urban forests are increasingly used to justify investment in their intentional management (Nowak & Greenfield, 2018). To estimate the environmental benefits of the trees in this study we used the free i-Tree Eco software suite developed by the USDA Forest Service (i-Tree, 2018). This software, used previously in many published studies of the benefits of urban forests, provides estimates of canopy cover, carbon sequestration, and avoided runoff among others (i-Tree, 2018; Song *et al*., 2018).

Tree Replacement Sites Chosen for Analysis

Results of a previous analysis of potential tree replacement along all Broadway Ave. within PSU boundaries indicated that replacing the trees that are in the poorest health and overall condition in Phase One would reduce the negative impacts to ecosystem services that necessarily occur when large, established trees are replaced (Brown, Moore, & Gerwing, *unpublished data*). Thus, in selecting sites to recommend for Phase One tree replacement we focused on existing trees that were in generally poor health and condition. Additionally, we wanted to identify groups of trees for replacement with the intention that replacing several trees together might generate more enthusiasm for the educational and public relations aspects of the overall "arboretum" project than widely spaced trees would.

Based on the above criteria, we selected the six Norway Maples in front of Cramer Hall on the west side of Broadway Ave (between Montgomery St. and Mill St.) for replacement analysis. The seven Norway Maples on both sides of Broadway between Harrison and Montgomery Streets also met these criteria but we have not yet completed a replacement analysis for these trees.

Modelling Methods & Tree Varieties Chosen for Analyses

We used i-Tree Eco software to estimate the ecosystem services provided by the six trees at our recommended replacement sites for three time periods: 0, 5, and 10 years following planting.

We assumed that all newly planted trees, project year zero, would have a 2.5" caliper size, as per City of Portland planting requirements, and be 6-10' tall. To estimate tree sizes for project years 5 and 10, we assumed a 0.1"/year diameter growth rate across all tree species (Palmas et al., 2016). For average height growth, if the tree species was considered slow growing we estimated 3' over the span of 5 years, 5' for moderate growing, and 7' for fast growing trees (Table 1). We used the growth rate information provided in the PSU Broadway Street Tree Study and Planting Plan to determine if trees were slow, moderate, or fast growing. We also used from the Arbor Day Tree Guide which designates slow growth as a plant that grows 12" or less per year; medium growth as 13 to 24" of growth per year; and fast growth to 25" or greater to get the numbers we used for our analysis (Dirr, 1990).

We compared four planting scenarios in terms of the estimated ecosystem services they would provide (See Table 1 for tree varieties included in each scenario):

1) No tree replacement - leaving the existing Norway Maples and assuming none of them died over the 10 years.
2) Broadway Arboretum Planting Plan- trees recommended in the Broadway Arboretum Tree Study & Planting Plan for the study area (Anonymous, 2018?).
3) Evergreen Trees - chosen to maximize avoided stormwater runoff and grow to similar mature heights as those in the Broadway Arboretum Planting Plan and be appropriate for the size planting strip.
4) Fast-growing Trees - chosen for rapid replacement of canopy cover lost with the removal of the large Norway Maples and grow to similar mature heights as those in the Broadway Arboretum Planting Plan and be appropriate for the size planting strip.

Table 1. Estimated height growth over a 5 year period for the tree species used to model the impacts of tree replacement on ecosystem services in three different scenarios. Each scenario includes 6 trees.

Tree variety	Height growth rate (ft) over 5 years	Broadway Ave. Planting Plan	Evergreen trees	Fast growing trees
Turkish Hazelnut	Slow (3)	1		
Lavalle Hawthorn	Slow (3)	1		
Silverleaf Oak	Moderate (5)		2	
Marina Strawberry Tree	Moderate (5)		2	
Sweet Bay Magnolia	Moderate (5)		1	
Chinese Pistache	Moderate (5)	2		
Chancellor Linden	Moderate (5)	1		
Norway Maple	Moderate (5)			
Eye Stopper Cork Tree	Fast (7)			1
Emerald Sunshine Elm	Fast (7)			2
Crimson Spire Oak	Fast (7)			1
Hardy Rubber Tree	Fast (7)	1		2
Forest Green Oak	Fast (7)		1	

Modelling Results, Planting Recommendations, & Caveats

As expected, all three tree replacement scenarios resulted in substantial decreases in ecosystem services compared to the existing large trees and these decreases persisted over the 10 years that we modelled (Table 2) although we need to emphasis that our “existing tree” scenario assumed zero mortailty of the existing trees over 10 years.

We did not find that fast-growing trees generated more canopy cover than those recommended by Broadway Arboretum Planting Plan. At project year 10, each of these scenarios had recovered only about 10% of the canopy lost with the removal of the large trees (Table 2). Both of these scenarios did, however, have more canopy cover than the Evergreen tree mix at year 10. It is possible that finding even faster growing species than those we selected and, possibly, getting more precise estimates of tree growth rates might affect this comparison.

We also failed to support the hypothesis that an evergreen tree might increase avoided runoff compared to those recommended by Broadway Arboretum Planting Plan. At year 0 the Evergreen Trees had a slightly higher value for avoided runoff than the other two replanting scenarios but that reversed by year 10 (Table 2). It is important to note that our selection of evergreen trees was limited by the necessity for them to be approved street trees. Trees like the Sweetbay Magnolia and Strawberry Tree are smaller, more slow growing trees compared to typical PNW evergreen trees, which would influence their ability to affect runoff. Additionally, we have some concern that the i-Tree program might not calculating stormwater avoidance

correctly for the PNW where we get most of our rain during the winter months after the leaves have dropped from deciduous trees. This is a technical issue that might be worth looking into a bit more closely.

As expected, the amount of carbon stored by the replacement trees was much less than the larger trees they replaced and they were projected to have stored just over 1% of the amount of carbon in the existing trees by project year 10 (Table 2). Carbon sequestration rates, on the other hand, are projected to recover more quickly with replacement trees projected to achieve 60% of the carbon sequestration of the existing trees by project year 10. Interestingly, modelled carbon sequestration rates were higher for evergreen trees overall. The moderate growth rate of Strawberry Trees and Silver Leaf Oaks and their ability to photosynthesize year-round may contribute to these higher rates.

Lastly, having a small sample size of only 6 trees was not likely sufficient to parse out the benefits of all fast-growing broadleaf trees versus a mix of slow to fast-growing broadleaf trees. Overall, we suggest planting majority fast-growing broadleaf trees with a mix of slower and medium-growing perhaps evergreen, trees for creating a layered canopy.

Table 2. Estimated ecosystem services provided by the existing trees and three tree replacement scenarios for the 6 trees on the West side of Broadway Ave. in front of Cramer Hall at 0, 5, and 10 years following replacement.

Ecosystem Services					
	Tree Cover (Sq. ft)	**Pollution Removal (lbs/year)**	**Carbon Storage (tons)**	**Carbon Sequestration (lbs)**	**Avoided Runoff (Cubic ft/year)**
Year 0					
Existing Trees	4181.76	1.950	4.456	64.990	57.980
Broadway Planting Plan	75.40	0.056	0.026	25.470	2.086
Evergreen Trees	75.40	0.067	0.028	26.680	3.862
Fast-Growing Trees	75.40	0.058	0.026	25.810	1.963
Year 5					
Existing Trees	4181.76	1.988	5.027	69.800	59.430
Broadway Planting Plan	217.8	0.164	0.042	32.940	5.624
Evergreen Trees	130.68	0.104	0.044	34.500	5.981
Fast-Growing Trees	174.24	0.129	0.041	33.110	4.410
Year 10					
Existing Trees	4181.76	1.928	5.048	70.090	57.090
Broadway Planting Plan	435.6	0.351	0.062	40.940	12.310
Evergreen Trees	174.24	0.146	0.064	42.980	8.417
Fast-Growing Trees	479.16	0.361	0.061	40.970	12.320

Conclusion & Future Directions

We didn't find any combinations of trees that performed significantly better over 10 years of modeling of canopy cover and stormwater avoidance than than those that were suggested in the Broadway Arboretum plan thus lending a bit more support to the overall recommendations in that plan. Instead of generating an alternative list of tree recommendations, the most significant contribution of our project might be using an ecosystem services framework as one source of information to analyze and compare different tree planting alternatives at PSU. To continue to build on this approach and these analyses we recommend:

- Reaching out to regional nurseries for recommendations of additional tree varieties that might be included in the Arboretum with an emphasis on fast-growing and/or evergreen varieties.
- Finding more precise growth data (both diameter and height) for the tree species to be modelled.
- Better understanding how i-Tree calculates avoided runoff to make sure it is properly accounting for the seasonality of rainfall in Portland.
- Growth monitoring of newly planted trees at PSU to understand how actual growth rates compare to estimated growth rates.
- Expanding this analysis to other sections of campus to include trees in more open spaces in addition to street trees.

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