Urban Forestry & Urban Greening 23 (2017) 104–112

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Original article

Patterns of urban forest composition in Utah's growing mountain communities

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ARTICLE INFO

Article history:
Received 17 May 2016
Received in revised form 2 March 2017
Accepted 2 March 2017
Available online 6 March 2017

Keywords:
Afforestation
Tree diversity
Water use
Urban development

ABSTRACT

Urban forests provide critical ecosystem services in cities of the Western United States, including regulating thermal extremes, supporting biological diversity, and providing cultural and recreational services. However, these services may come with trade-offs such as heavy water demand in arid environments. Thus, afforestation and its effect on the water budget – as well as other ecosystem services – can be contingent on the species composition of urban forests. Choice of tree species, in turn, is influenced by historical contingencies and development context. The objective of this study was to identify differences in tree species composition between four broad classes of urban development in Heber Valley, Utah, with classes defined by establishment age, lot size, and location within the urban-suburban environment. Publicly available information was used to categorize residential and commercial areas, and standard forestry techniques were used to collect data on trees in a stratified random survey of lots in each category. Older, established housing had the highest tree basal area and species richness per hectare, and exurban (rural, dispersed housing) developments had significantly higher species diversity than new tract housing. Because it appears that exurban communities are being replaced by tract housing, there is evidence that tree diversity may be lost. Another important aspect of community structure in urban forests is the ratio of conifers to broadleaf trees because of fundamental differences in water use patterns. Conifers were twenty-five percent of the average lot basal area in exurban and thirty-five percent in established neighborhoods, as opposed to five percent in tract housing. If functional groups are used as predictors of water use in irrigated urban systems, water demand is likely to increase with the expansion of low-diversity, angiosperm dominated tract forests in the Western US in the coming decades.

1. Introduction

Population growth and the accompanying development is a trademark of the American West. What began for European-American settlers as an ongoing resource-extraction boom is now a migration spurred by an amenity- and recreation-based economy and a culture of land speculation and development.[1] The population of the West has increased steadily since the 1850s, currently at 23.6% of the nation's population.[2,3] Many people, paradoxically, are drawn to the West by the very open spaces that they increasingly fill. Although wilderness and rangeland still exist in large measure in the West, urban and suburban development is spreading in this landscape, causing major shifts in land use.[4]

The overall pattern of ecological change with development has been similar within the intermountain west of the US. Historically, grasses and shrubs such as sagebrush and bunchgrasses dominated mid-elevation ecosystems.[5] European-American settlers introduced dryland and irrigated agriculture in the valleys, supplanting the native vegetation with crops such as alfalfa and pasture grasses and impacting the remaining native plant communities with livestock grazing.[6,7] Now, suburban and urban housing, with accompanying afforestation, often replaces crop-

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[2] Ibid.
[3] U.S. Census Bureau, 2014.
[4] Hansen, A. J. et al. Effects of exurban development on biodiversity: patterns, mechanisms, and research needs, *Ecological Applications,* 15 (2005), 1893–1905
[5] Fiege, Mark Irrigated Eden: The making of an agricultural landscape in the American West (University of Washington Press, 1999), 42.
[6] Ibid.
[7] Worster, Donald *Wealth of Nature: Environmental History and the Ecological Imagination* (Oxford University Press, 1994).

http://dx.doi.org/10.1016/j.ufug.2017.03.001
1618-8667/

land or rangeland, representing an even greater change from pre-European conditions.[8] Afforestation, or the introduction of landscape trees onto the previously unforested land, is the most direct ecological change represented by the shift from agricultural to residential land.[9] Afforestation provides ecosystem services to urban areas such as carbon sequestration,[10] shade and evaporative cooling[11] retention of water runoff, air purification,[12] and habitat for wildlife,[13] as well as aesthetic improvement. For this reason, urban forests are generally desired and encouraged with development. Particularly in the West, however, irrigated forest has a structurally and functionally different ecological makeup than the native shrublands or seasonal cropland, with ecological costs as well as benefits.

Water use is one of the most important environmental costs to consider as a result of afforestation in the semiarid West. As climate change increases the possibility of summer water shortages,[14,15] landscaping continues to claim a large portion of the water budget. For example, in Utah, outdoor water use was estimated at 64% of residential water use in 2010.[16] Landscaping choices for municipalities and individuals can be made looking to decrease water use while still maintaining the ecosystem services provided by trees. There are multiple ways to approach this, but plant functional traits play a large role in tree water use, making species composition an important variable. Water use is influenced by anatomical constraints such as xylem structure and by physiological responses to the environment such as stomatal conductance or photosynthetic rate. These result in species-specific traits such as level of water-use efficiency, or the amount of water required for a given amount of growth.[17] Water use also differs between broad classes of trees: studies have shown that in native systems, conifers to have consistently lower transpiration rates than angiosperms, which typically translates to lower whole-tree water use. This is likely due to conifers' more restricted vascular structure as well as other aspects of wood anatomy,[18] and makes the conifer-angiosperm ratio a useful comparison when considering neighborhood tree water use. While there are other factors influencing water use, this inherent variability in tree water use supports the need for examination of trends in species selection for landscape trees.

Species composition has other implications for urban ecosystems as well. In particular, urban forests can be a significant source of biodiversity, which is generally viewed as beneficial. Species and structural (size, shape, age) diversity of vegetation in patches are important variables in habitat availability and thus faunal diversity.[19,20] More habitat diversity, as well as inclusion of tree species native to the surrounding area, can provide more opportunities for the preservation of native animal species (especially birds) and rich interactions between them.[21] Urban biodiversity has aesthetic benefits for residents as well, from visual interest to education. However, urban tree diversity isn't completely unambiguous in its benefits; high numbers of exotic species can lead to invasions, and ecological benefits vary by species.[22] This is one of many tradeoffs necessary to consider when planting urban trees.

In characterizing urban forest composition, previous studies have looked at correlations of composition to demographics.[23] and land-use type,[24] but few have categorized neighborhoods by development patterns. This is particularly interesting in the West, where development has occurred in waves in an open landscape, resulting in layers of development based on period, usage or function, and proximity to urban centers. Travis (2007) identified several development categories in the West resulting from these factors.[25] "Metrozones" are hotspots of residential and commercial development that sprawl out from multiple city centers, comprising suburbs characterized by homogeneous tract housing as well as older city cores made up of heterogeneous established housing. Another relevant category is the "exurbs," or "dispersed, low density residential land" sought out by people who desire a rural lifestyle with access to city conveniences. These patterns in turn are likely to represent distinct urban forest communities, and this is the basis of our study of patterns of urban forest composition in conjunction with gradual urban development.

Afforestation, though only one aspect of ecological change, plays a critical role in urban biodiversity and resource use and has a dynamic relationship with the patterns of development. The Heber Valley in northern Utah, USA provides an ideal case study to examine this relationship and its consequences. Utah is the second fastest-growing state in the country by percentage[26] and Heber City is the seat of its fastest growing county at a 7.1% annual increase.[27] Situated in a semiarid shrubland and agricultural zone, this area is part of the Salt Lake City-Park City metrozone with elements of exurban development. This region also displays several distinct development categories characteristic of the West, from extremely low-density exurban housing to dense, young tract housing. Trees are dominant in its suburban landscape; the Heber City General Plan establishes a standard of "well-landscaped, tree-lined streets".[28] In this setting, we asked the question, Are there differences in basal area, stem density, species richness and evenness, and plant functional type in the urban forest of distinct classes of development? To address this, we used publicly available housing data and geographic development trends to categorize four

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