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An economic value assessment of ecological services in the tree community at Winona State University Arboretum

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Abstract

Trees possess intrinsic and extrinsic attributes that contribute to enhancing high environmental standards in a majority of landscapes, also while improving quality of life for human communities and other biota. Winona State University was recognized recently as a Tree Campus USA, the only institution of higher education within the Minnesota State Colleges and Universities (MnSCU) system to achieve this distinct honor. To retain this honorable recognition, a tree inventory was conducted during fall 2015 to evaluate, more tangibly, the economic benefits of its campus tree community and also to develop a data base that could assist with future management practices of this newly established Arboretum. Assessing tree density, size (DBH), diversity, and overall condition of this community (*n*=1,482) allowed the researchers to estimate a monetary value of the more specific ecological services that are provided by trees. In this study, we considered the potential economic value in reference to: energy savings, storm water capture, esthetic value, air quality, and carbon sequestration. The total annual value provided by trees on our campus, based on the five variables, was estimated to be $90,974, whereas the total annual cost for maintaining (e.g., pruning, replacement) the tree community was $18,553. This suggests that for every $1.00 spent on trees in 2015, Winona State University gained $4.90 in return. This study demonstrates that there are tangible economic benefits in maintaining a healthy arboretum at our institution, besides enhancing educational and research endeavors for students and more educational opportunities for the Winona community.

Keywords: education, landscape, Tree Campus USA, trees value, urban environment

INTRODUCTION

The conservation of trees in an urban environment provides a broad variety of environmental benefits (Wolf and Robbins, 2015), such as improving air quality (Sæbø et al., 2013; Nowak et al., 2006), increasing opportunities for health (Sandifer et al., 2015) and recreational activities (Donovan et al., 2013), enhancing a place-based education for all citizens (Borsari, 2012; Louv, 2005), and providing many additional ecological services to the landscape. Native trees and ornamental species have potential to amplify the distinctive attributes of a specific bioregion, enhancing its attractiveness and thus become a communal patrimony and a cultural heritage worthy of care and conservation.

Since 2007, an interest has been emerging at Winona State University to maintain and conserve the tree collection on its campus, with a purpose of making the open space available and more accessible to visitors, students, and the Winona community. Also, the earlier publication of a notable book (Meyer and Grier, 2005) that describes the diversity of trees on campus fostered an enthusiasm for tree conservation. Thus, a diverse group of university employees, students, and community members came together in 2012 to establish the All-University Land Stewardship & Arboretum Committee and through its work

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Winona State University was recognized in 2014 as a Tree Campus USA by the Arbor Day Foundation.

The purpose of our study was to analyze tree inventory data collected in 2015 to assess the number, species diversity, size (DBH), location, and condition of the campus treecommunity. This work has become a routine practice at Winona State University to improve the management of its open space and also to fulfill the requirements for maintaining the Tree campus USA status, through the years. Finally, this survey was prompted by the need for an evaluation of the ecological services provided by trees and an estimation of the economic benefits provided by establishing the arboretum on our campus.

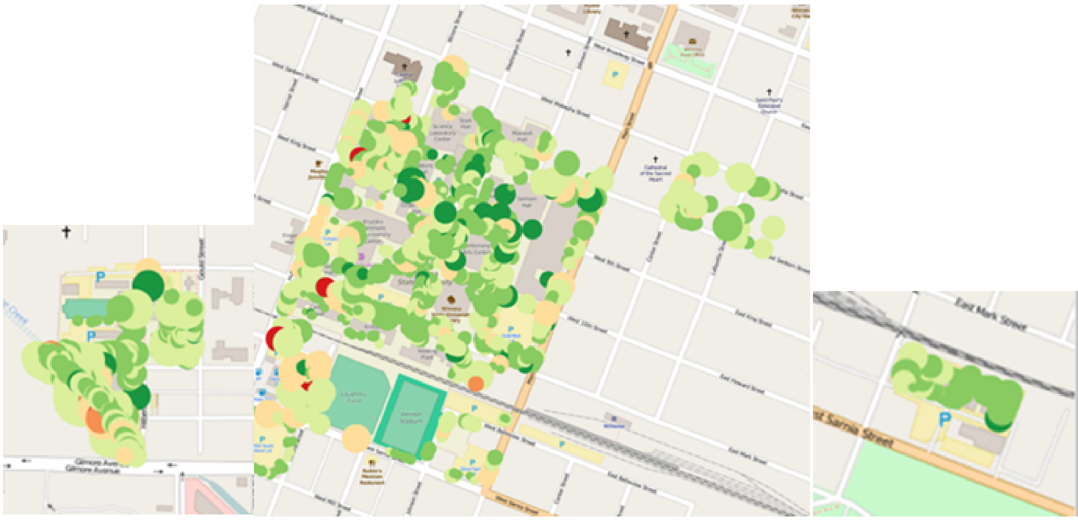
MATERIALS AND METHODS

Site description

The open space available at Winona State University includes 50.6 ha (main, east, and west campuses), in addition to a bur oak savannah (28 ha) and a mature forest (48.5 ha). The savannah and forest properties are located on the outskirts of town, on the distinctive bluffs (183 m above sea level) of our unique driftless bioregion, in southeastern Minnesota.

Methodology

The survey considered the trees of the main, east, and west campuses located in the City of Winona, Minnesota (44°N; 91.6°W) and it was accomplished between August and September 2015 (Figure 1).



a) b) c)

Figure 1. Tree canopy cover (estimated at 22.8%) on the a) west, b) main, and c) east sections of the Winona State University campus (images are not to scale).

The survey data were collected and uploaded on TreeKeeper® 7.7 Software Management of Davey Resource Group for reference in current and future tree management practices. These data included tree species identification, location, size (DBH), condition, risk assessment, maintenance needs, further inspection dates, over-head utilities (e.g., power lines), and date of inspection. Tree diversity was evaluated by comparing survey data to the 10-20-30 rule as proposed by by Santamour (1990), for determining tree diversity in urban forestry. The rule suggests that a tree community in an urban environment should have no more than 10% of any one species, 20% of any one genus, or 30% of any family to be considered sufficiently diverse. Contrary to the Shannon-Weaver or the Simpson's indices of diversity, the rule is a goal, not a measurement. Despite its limitations, we decided to assess the University's tree population against the 10-20-30 rule as it is accepted as a best practice among urban foresters to learn rapidly whether or not our tree community was diverse.

The survey variables served to assess the potential economic value of the trees in reference to energy savings, storm water capture, aesthetic value, air quality, and carbon sequestration.Thei-Tree software (available at: https://www.itreetools.org/) of the USDA Forest Service was employed for this purpose.

RESULTS AND DISCUSSION

The tree community of the WSU Arboretum (*n*=1,482) had 70% of its trees (1,037) on the main campus, 27% (402) located in the west campus, and 3% (43) on the east campus. The trees' overall condition was rated using six different categories (Table 1).

Table 1. Categories showing percentages of the overall condition of the trees at the WSU arboretum.

Assessment category[1]	Number of trees in a specific, overall condition	Percentage of the tree population (%)
Dead	9	0.6
Critical	6	0.4
Poor	80	5.6
Fair	408	28.3
Good	868	60.3
Very good	57	4.0

[1]Dead indicates that the tree is no longer living (totally defoliated, desiccated). Critical indicates serious injuries to trunk and branches, or roots that impede buds opening >50%. Poor indicates that tree injuries affect buds opening <50%. Fair indicates that only minor injuries have been detected and that these do not appear to have affected the tree canopy. Good indicates minor to lack of injuries and vigorous/homogeneous growth, whereas Very good indicates the absence of blemishes and an excellent health of the tree.

A single value of tree condition (Dead to Very good) that takes into account both tree health and structure was used based on best practices for tree inventories (Bond, 2013). A majority of trees (64.3%) were in good and/or very good condition. Dead trees or stumps (0.6%) were conifers, mainly pine trees (*Pinus* spp.), whose death and/or removal was most probably linked to lawn treatments with the herbicide aminocyclopyrachlor (Imprelis®) that were done in 2011. The tree community met the 10-20-30 rule for diversity (Santamour, 1990), with 99 species (including cultivars), of which 18 where most highly represented at the WSU Arboretum (Table 2).

The genus *Fraxinus* (ash) comprised 14% of the tree population, followed by *Acer* (maple), 10%; *Thuja* (white cedar), 10%; *Malus* (apple), 7%; *Picea* (spruce), 6%; *Betula* (birch), 5%; *Juglans* (walnut), 5%; *Ulmus* (elm), 5%; *Celtis* (hackberry), 4%; *Syringa* (lilac), 4%; *Tilia* (basswood), 4%; *Amelanchier* (serviceberry), 2%; *Ginko* (ginko) 2%; *Gleditsia* (honeylocust), 2%. Oak trees (*Quercus* spp.) and pine (*Pinus* spp.) were represented at 2% each of the total tree community on campus (84% among all the genus taxa), whereas the remaining 16% represented other species in 37 different genera. The gingko tree (*G. biloba*), although a non-native species, has been planted extensively in past years because of its adaptability to a variety of soil conditions, longevity, and resistance to pathogens (Meyer and Grier, 2005).

Size (DBH) differed broadly among the most representative taxa of the tree community of the WSU Arboretum (Table 3). Common hackberry and white ash were some of the largest trees on campus, with more than 10% of individual trees of both species >60 cm DBH. Most species had size distributions centered in size classes between 10 and 45 cm DBH.

Table 2. Percent abundanceof the most common tree speciesinthe Winona State University Arboretum.

Scientific name	Common name	Percentage (%)	Native species
Thuja occidentalis L.	Northern white cedar	10.0	Native
Fraxinus pennsylvanica	Green ash	9.3	Native
Malus spp.	Apple/crabapple	7.0	Non-native
Juglans nigra	Black walnut	4.3	Native
Celtis occidentalis	Common hackberry	4.0	Native
Syringa reticulata	Lilac, japanese tree	4.0	Non-native
Picea pungens	Blue spruce	3.5	Non-native to MN
Fraxinus americana	White ash	3.3	Native
Acer rubrum	Red maple	3.1	Native
Ulmus americana	American elm	2.7	Native
Acer platanoides	Norway maple	2.6	Non-native
Betula nigra	River birch	2.4	Native
Tilia americana L.	American basswood	2.1	Native
Amelanchier canadensis	Canadian serviceberry	2.0	Non-native
Tilia cordata	Littleleaf linden	1.9	Non-native to MN
Gleditsia triacanthos	Honeylocust	2.0	Native
Betula papyrifera	Paper birch	1.6	Native
Picea glauca	White spruce	1.6	Native

Table 3. Size distributions (diameter at breast height [DBH]) of the 10 most common tree species in the WSU Arboretum. Values are percentages.

Species	DBH class (cm)								
	0-10	10-15	15-30	30-45	45-60	60-80	80-100	100-120	>120
T. occidentalis	62.0[1]	30.0	8.0	0.00	0.00	0.00	0.00	0.00	0.00
F. pennsylvan.	0.00	15.8	43.6[1]	18.5	15.6	6.1	0.4	0.00	0.00
Malus spp.	5.6	38.2[1]	36.0	13.0	1.2	0.00	0.00	0.00	0.00
J. nigra	0.00	21.7	42.8[1]	21.0	10.5	2.6	1.4	0.00	0.00
C. occidentalis	0.00	25.2	27.4[1]	8.0	12.8	14.2	10.1	1.1	1.2
S. reticulata	0.00	47.7	48.0[1]	4.3	0.00	0.00	0.00	0.00	0.00
P. pungens	22.8	22.8	22.8	31.6[1]	0.00	0.00	0.00	0.00	0.00
F. americana	0.00	0.00	21.4	48.3[1]	20.1	5.1	5.1	0.00	0.00
A. rubrum	0.00	6.2	78.4[1]	10.2	5.2	0.00	0.00	0.00	0.00
U. americana	0.00	24.3	59.1[1]	9.4	2.3	2.9	0.00	2.0	0.00

[1]Most abundant size categories.

Energy savings

Trees can be effective in mitigating the indoor climate of buildings and assist significantly with reducing the need for electricity (Pandit and Laband, 2010). Donovan and Butry (2009) conceded that trees shading a building for about 50% of its surface can lower the electricity demand of the building by up to 14% when compared to an unshaded building of similar dimensions. The iTree software reported that the energy saved by the current tree community at Winona State University was 142.6 MWh, comparable to the energy consumed in a year timeframe by 13 typical households in the US. Tree shading of buildings saved WSU $21,362 in electricity costs in 2015. Tree shade reduces the deterioration of paved surfaces like streets and parking lots (McPherson and Muchnick, 2005), thus improving maintenance cost savings a step further.

Storm water capture

The iTree software showed that current tree canopy covers 22.8% of the campus arboretum and that in 2015 the trees intercepted about 4,027,375 L of water (>4,000 t). The retention of water in soils is a valuable, ecological service that mimicks the functioning occurring within forest ecosystems. This is due to the great potential of trees to develop massive root systems, which greatly reduce soil loss,thus enabling soils to increase their water retention capacity and almost eliminate soil erosion (Day and Dickinson, 2008). In addition to this, storm water capture exerted by trees at WSU reduced non-point source pollution by water run-off and soil erosion, saving the university $28,832 that otherwise could have been spent to dispose of water excesses due to rain and ice melting during spring (March-April).

Esthetic value

In a recent review article, Wolf and Robbins (2015) explained that esthetics related to tree canopy cover in urban settings enhances property economic value. In addition to this, landscape esthetics through trees has potential to attract shoppers to retail areas, where they may spend more time and also money in these 'green' spaces (Wolf, 2014). Therefore, high tree densities enhance tourism and economic revenues (Deng et al., 2010), whereas property value in urban areas is expected to rise up to 20% of its original price when trees are present (Kane and Kirwan, 2009). The esthetic value of the WSU arboretum was estimated at $32,426 per year, as calculated by the iTree software.

Air quality

The improvement of air quality provided by trees has been quantified for all states in the US by Nowak and his collaborators (2014), who pointed out the importance of growing trees in urban areas and the health benefits provided by these to reduce respiratory illnesses. A tree line already is capable of improving the air quality inside buildings adjacent to it, by trapping and thus reducing up to 50% of the particulate matter (PM) from the air (Maher et al., 2013). The iTree software calculated the benefits for improving air quality at the WSU campus which amounted to a value of $4,767 in 2015. More specifically, our tree community was capable of capturing 59.3 kg of ozone (O_3), 55.1 kg of nitrous oxide (NO_2), 296 kg of sulphur dioxide (SO_2), 43 kg of volatile organic compounds (VOCs), and 79 kg of particulate matter.

Carbon sequestration

The monetary value estimation based upon measurements of carbon dioxide (CO_2) sequestration accomplished by trees has been achieved with accuracy since the last decade (Nowak et al., 2006). In 2015, the campus tree community sequestered 216,209 kg of CO_2 and the annual value of this service was estimated at $ 3,587, as calculated by the iTree software. At this time, the maximum carbon storage capability of the arboretum (1,218,523 kg) has an economic value of $20,148 for carbon sequestration at Winona State University.

CONCLUSIONS

The following conclusions can be drawn from our study:

- Overall, the tree community of the WSU Arboretum contributed approximately $90,974 in economic and environmental benefits in 2015.
- The aesthetic value attributable to campus beautification due to trees was estimated at $32,426 year^{-1}, the largest annual economic value (35.6%) among the economic benefits that were considered in this study.
- The budget for tree care in 2015 was $18,553, resulting in a return of $4.90 for every dollar spent for maintaining trees on the WSU campus Arboretum.

Trees possess great potential for enhancing the aesthetic, an education about 'place' and ultimately, the economic value of landscapes. Arboreta and other examples of gardens that rely primarily on native plants can become powerful spaces to reconnect people (especially youth) with nature and the ecological services and functions they provide within urban environments (Tallamy, 2009). Nature-deficit-disorder syndrome (NDDS) was presented by Louv (2005) as the societal malady that has been affecting city dwellers for the last fifty years, due to a severing of connections with the outdoors and nature. In the meantime, a relentless expansion of sub-urban areas in cities has been amplifying the symptoms of NDDS (Louv, 2011) thus, legitimizing the urgent needs for conservation of open spaces and a restoration of these into biologically diverse habitats. The estimated aesthetic value produced by the tree community at Winona State University was the highest annual value among those of the five categories that were considered in this work. Also, in a recent case-study that considered first-year students at a university in the Midwest, Harmening and Jacob (2015) found that 50% of their respondents appreciated the campus and outdoor space beauty, attributing to these characteristics the main reason for their well-being.

Finally, and most importantly, an education about trees and plants remains pivotal to the 'raison d'être', or 'reason for being' of our Arboretum at Winona State University. A multitude of transformative educational activities can be taught through an employment of trees as a theme of instruction to make learning authentic and experiential. To this end, Bauerle and Park (2012) reported that students (including non-science majors) responded successfully, and achieved academically, in a course in plant science when learning included field-trips and outdoor activities like tree climbing.

In sum, we recommend that future landscaping efforts will rely ever more on tree species that are native to our bioregion (Rathke, 1995). Such an approach will amplify the resilience of the plant community at the Arboretum, while enhancing the educational potential that our distinctive tree collection already has. Also, future management practices at the Winona State University Arboretum should strive to be adaptive, minimize (or better eliminate) the use of agrichemical products, engage students in placed-based education as predicated by Orr (1994), while embracing the philosopy that the campus is an ecosystem (Borsari, 2012). Through these and similar principles, an educational approach that will strive for giving emphasis to living systems will benefit the entire campus community, making trees the new focus of instruction across curricula, while engaging in this transformative education all strata of the Winona State University population and beyond.

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