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Cover Page Footnote
I would like to thank Dr. Christie Klimas for all of her guidance, support, and patience with me throughout this project. I would like to thank Dr. Jim Montgomery, who offered us his extensive knowledge of PWS and often accompanied us to PWS. The Department of Environmental Science and Studies at DePaul University has been relentless in their support of this project, and for that, I would like to thank you. And lastly, I would like to thank my teammates, Michael Berry, Carla Ramirez, Allison Williams, and Ashley Young for all of their help and laughs, in and out of the lab and field.

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Ecosystem Services of Prairie Wolf Slough: Quantifying Carbon Storage

Megan Hoff*
Department of Environmental Science and Studies

ABSTRACT  This project is a case study of the benefits of a natural area in Highland Park, Illinois, Prairie Wolf Slough (PWS). A series of experiments were set up to quantify the carbon storage potential of PWS. The results presented here provide an estimate of the aboveground biomass in the forest of PWS with a preliminary estimate of the stored carbon’s value. This is done using the social cost of carbon. It was found that species carbon storage differed based on the number of individuals for each species and their physical size. In addition, using the 2015 discount rate of 3%, which is $12, the forest at PWS would be worth $15,588.99 for standing carbon. Using the discount rate of 5%, which is $36, the forest at PWS would be worth $50,664.21 for standing carbon. Without the assignment of a monetary value on terrestrial natural capital, and any ecosystem service for that matter, the default value is zero and/or unrecognized, and, consequently, exploited. This de facto exclusion of the natural world’s value in decision making has led to a call to value the services provided by nature, as is the goal and expected contribution of this paper.

INTRODUCTION

The quantification of the ecosystem services in urban habitats is an important emerging trend of urban ecology, catalyzed by the advent and popularization of urbanization. Over 80 percent of the world’s population lives in an urban area, illuminating the growing importance of providing urban green spaces and vegetation (U.S. Department of Agriculture, Forest Service [USDA], 2014a, para. 1). According to the U.S. Forest Service “Urban forests broadly include urban parks, street trees, landscaped boulevards, public gardens, river and coastal promenades, greenways, river corridors, wetlands, nature preserves, natural areas, shelter belts of trees and working trees at industrial brownfield sites” (USDA, 2014a, para. 2). Trees located in urban areas are often chosen based on a conglomerate of aesthetic appeals, economic interests, and overall hardiness, as the urban environment is harsh. A negative result of this
can be the development of monocultures, which decreases biodiversity and thus resilience. Monocultures increase the susceptibility of trees to diseases and pests, which has economic and social repercussions. They also have implications for the functional significance (ecosystem services) and diversity of urban forests (Dunn & Heneghan, 2011, p. 110).

The urban forest provides multiple ecosystem services and human health benefits, justifying investment and research in this resource. The primary benefits urban trees provide are air pollution removal, improved social wellbeing, energy usage reductions in buildings, and strengthening of the local economy. First, trees improve air quality “by absorbing gaseous pollutants through their leaves [as well as] binding or dissolving water soluble pollutants onto leaf surfaces” (USDA, 2014b, para. 2). Second, trees foster societal health. Tree planting activities can foster community-building while engaging community members with their environment (USFS, 2014b, para. 5). Moreover, the presence of trees in a community significantly contributes to lower rates of asthma and obesity (Alfsen, Duval, & Elmqvist, 2011, p. 214). Third, trees cool cities and save energy. In the summer, trees provide shading, which cools buildings and reduces energy costs. In the winter, trees insulate buildings by blocking wind (USDA, 2014b, para. 1). For example, “Based on average energy costs in 2009, trees in the Chicago region reduce energy costs from residential buildings by an estimated $44.0 million annually” (Nowak, Stein, Randler, Greenfeld, Comas, Carr, & Alig, 2010, p. 8). Finally, trees have economic benefits, which indirectly translate into a greater quality of place. It is estimated that trees “increase property values by 10 to 20 % and attract more homebuyers” (USDA, 2014b, para. 3). In addition, urban parks create space for festivals and other events which generate revenue for the local economy. This simultaneously aids in community-building (USDA, 2014b, para. 3).

Urban forests are also a source of natural capital via the numerous ecosystem services they offer. The following is a general list of notable ecosystem services that urban forests offer: source of food for birds and other animals, provides trimmings for composting or fuel, acts as a genetic resources through their species diversity, reduces the runoff rate depending on the canopy size and foliage, and plays a role in water flux (Douglas & Ravetz, 2011, p. 253-254). Finally, and most important to this study, trees sequester carbon. This is done through their uptake of carbon for tissue growth, an especially significant benefit given the negatively foreseen and experienced effects of global climate change (Nowak, et al., 2010, p. 15).

In the literature, researchers have tried to determine and amalgamate the best methodology for modeling and estimating carbon storage. Bateman and Lovett (2000) found that the carbon flux is determined by the livewood carbon storage, emissions from products and waste, and storage and emissions from soil (p. 301). They also found that sequestration fluxes are impacted by forest management techniques. Similarly, Gomez-Baggethun and Barton (2013) “synthesize knowledge and methods to classify and value ecosystem services for urban planning” (p. 235). Lastly, Campbell and Tilley (2013) did a case study on the ecosystem services of a Maryland forest (p. 141), which is comparable to this project and the future research of this project.

This project is a case study of the benefits of a natural area in Highland Park, Illinois, Prairie Wolf Slough (PWS). PWS includes a wetland, prairie, and forest and a series of experiments were set up to quantify the carbon storage potential of PWS. The results presented here provide an estimate of the aboveground biomass in the forest of PWS with a preliminary estimate of the stored carbon’s value. This is done using the social cost of carbon (SCC). The social cost of carbon is a measurement of the costs associated with an increase of one metric ton of CO₂ (economic damage) as well as the benefits of a reduction of one metric ton of CO₂ (damage avoidance). “The SCC...includes, but is not limited to, changes in net agricultural productivity, human health, and property damages from increased flood risk” (U.S. Environmental Protection Agency [USEPA],
Using the different social costs of carbon discount rates, an estimation of the value of the aboveground biomass in the forest of PWS can be made.

METHODS

Two transects were inventoried that were 30 m in width and ran East-West parallel. The East-West direction was chosen to capture the topographic gradient from upland forest to the beginning of the wetland. Using satellite imagery from Lake County online maps (“Lake County Maps Online”, n.d.), land area for the total forested area in Prairie Wolf Slough was calculated (Figure 1) using the polygon function under the tools tab.

In each transect, biophysical data were used to calculate the total aboveground carbon pools in trees. This included measuring tree diameter at breast height (dbh) on trees greater than 10/cm, tree height using a hypsometer, and tree canopy area (m²). In addition, data were also collected on canopy classification and tree species. Trees that were unidentifiable were grouped into an “unidentified” category for the purpose of this study.

The tree biomass distribution system used was 20% in the crown, 60% in the merchantable stem, and 20% in the stump/root system (Husch, Miller, & Beers, 1982; Wenger, 1984). Thus, my analysis only gives 80% of the tree carbon, as I did not measure soil carbon. Aboveground biomass was converted from dbh (cm) to total aboveground biomass (kg) using species allometric equations from the compiled lists in Nowak (1993), Tritton and Hornbeck (1982), Barros, et al. (1999), and Jenkins, Chojnacky, Heath, and Birdsey (2004). Total aboveground biomass includes leaves, stems, and braches (see Table 1). For example, the allometric equation for White Oak is:

\[ wt = 1.5647 \times (dbh)^{2.6887} \]

where \( wt \) is in lbs and dbh is in inches

The weight was converted to kilograms using the conversion factor 1 lb = 0.45359237 kg and dbh was converted to centimeters giving the following equation:

\[ (1.5647 \times (86.3^{2.6887})) \times 0.45359237 = 9289.078557 \text{ kg} \]

This calculation method was repeated for every tree collected in the first two transects, which totaled 238 trees.

Next, using the guidelines provided by the Alabama Forestry Commission (n.d.), total aboveground dry tree biomass was converted to carbon equivalents. First, the total aboveground biomass was summed and converted from kilogram to short ton by multiplying by 0.5 to obtain a comparable weight. This was then converted to the carbon equivalent by multiplying by 3.67. Lastly, this was converted to the CO₂ equivalent in metric tons by multiplying by 0.9072.

The total aboveground biomass for each tree was summed and multiplied by the 2015 social costs of carbon, as found on the U.S. EPA’s website (“Social costs of carbon”). The discount rates of 3% and 5% were used, which means that the summed biomass was multiplied by $12 and $36, respectively.

RESULTS

The area of the total forest in Prairie Wolf Slough is approximately 46,977.44 m² or 11.608 acres. The area of transect 1 was approximately 3,250.40 m², constituting about 6.92% of the total forest. The area of transect 2 was
approximately 4,226.25 m², constituting about 8.99% of the total forest. Together, transects 1 and 2 constitute approximately 15.91% of the total forest. The total aboveground biomass for each tree was summed, giving a total of 1299.08217 metric tons of carbon storage. It was found that species carbon storage differed based on the number of individuals for each species and their physical size (Table 1).

The social cost of carbon provides an estimated value of the aboveground biomass in the forest of PWS. Using the 2015 discount rate of 3%, which is $12, the forest would be worth $15,588.99 for standing carbon. Using the discount rate of 5%, which is $36, the forest would be worth $50,664.21 for standing carbon.

**DISCUSSION**

This project quantified the carbon storage potential of aboveground biomass for a natural area. Every ton of carbon mitigated by terrestrial ecosystems translates into a reduction of greenhouse gas emissions in the atmosphere, and thus avoidance in damage costs. These damage costs are included in the social costs of carbon, a measurement of the costs associated with an increase of one metric ton of CO₂ (economic damage) as well as the benefits of a reduction of one metric ton of CO₂ (damage avoidance) (Conte, *et al*., 2011, p. 112). In 2011 U.S. Dollars, using the discount average values of 5%, 3%, and 2.5%, from the years 2015-2050 the EPA estimates the social cost of carbon to range from $12-$104. (USEPA, 2013, para. 3).

Without the assignment of a monetary value on terrestrial natural capital, and any ecosystem service for that matter, the default value is zero and/or unrecognized, and, consequently, exploited. This de facto exclusion of the natural world’s value in decision making has led to a call to value the services provided by nature, as is the goal of the Natural Capital Project at Stanford. However, this value is still but a shadow indicator of the true value of ecosystems. As the title of Rees’ (1998) publication: “How should a parasite value its host” (p. 49) suggests, the methods used to quantify the value of the environment do not do justice to its actual value. Whereas they do not capture the true value of the environment, they are a starting point for conversations between scientists, land planners, the government, and other stakeholders in the decision-making process.

Assigning a monetary value to carbon can be justified because it expands the pool of eligible market participants, increasing economic engagement while simultaneously accounting for a common externality in economics: the environment. However, there are permanence and leakage problems associated with the carbon market. Illegal logging, fires, soil disruption, and just the fact that trees eventually die and decay contribute to permanence issues, as the carbon stored in the tree biomass is released into the atmosphere. In addition, leakages may occur when landowners participate in offset markets. Setting aside a parcel of land for carbon sequestration purposes may put added economic pressure on other sites for agriculture or urban development use, thus “leaking” the carbon to other sites, even across the globe (Conte, *et al*., 2011, p. 114). In other words, offset markets do not eradicate the demand for land uses that result in carbon releases. Whereas there are reservations about how to best conserve and value natural landscapes in the face of urbanization, low-density development and future outdoor recreation demands, the future of carbon sequestration and urban forestry is a bright practice.

Future research will continue to inform the costs and benefits of different urban land management by adding a temporal component; dendrometer bands will be installed in the spring of 2015 on all sampled trees to look at how aboveground biomass changes over time. InVEST (The Natural Capital Project, n.d.) will also be used to compare Prairie Wolf Slough to an alternative likely scenario, an adjacent housing subdivision, to further account for the economic, social, and environmental benefits and costs of a natural area.
Table 1 Sum of the aboveground biomass (kg) for each tree species

<table>
<thead>
<tr>
<th>Tree Species</th>
<th>Sum of Biomass (kg)</th>
<th>Count of Tree Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Elm</td>
<td>1,221.92</td>
<td>4</td>
</tr>
<tr>
<td>Ash</td>
<td>503.79</td>
<td>2</td>
</tr>
<tr>
<td>Beech</td>
<td>38.25</td>
<td>1</td>
</tr>
<tr>
<td>Black Ash</td>
<td>866.27</td>
<td>7</td>
</tr>
<tr>
<td>Black Cherry</td>
<td>93.30</td>
<td>1</td>
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<tr>
<td>Black Walnut</td>
<td>755.82</td>
<td>6</td>
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<tr>
<td>Box Elder</td>
<td>162.17</td>
<td>1</td>
</tr>
<tr>
<td>Chestnut Oak</td>
<td>4,238.35</td>
<td>19</td>
</tr>
<tr>
<td>Chestnut White Oak</td>
<td>144.94</td>
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</tr>
<tr>
<td>Elm</td>
<td>494.60</td>
<td>7</td>
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<tr>
<td>Black Ash</td>
<td>468.87</td>
<td>1</td>
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<tr>
<td>Green Ash</td>
<td>2,721.15</td>
<td>8</td>
</tr>
<tr>
<td>Hickory</td>
<td>276.93</td>
<td>2</td>
</tr>
<tr>
<td>Kentucky Coffee Tree</td>
<td>69.79</td>
<td>1</td>
</tr>
<tr>
<td>Linden</td>
<td>695.86</td>
<td>2</td>
</tr>
<tr>
<td>Norway Maple</td>
<td>169.12</td>
<td>3</td>
</tr>
<tr>
<td>Peachleaf Willow</td>
<td>1,659.93</td>
<td>6</td>
</tr>
<tr>
<td>Red/Black Oak</td>
<td>61,932.55</td>
<td>91</td>
</tr>
<tr>
<td>Shagbark Hickory</td>
<td>268.02</td>
<td>2</td>
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<tr>
<td>Silver Maple</td>
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<tr>
<td>Slippery Elm</td>
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<tr>
<td>Swamp Cottonwood</td>
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<td>Swamp White Oak</td>
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<tr>
<td>White Oak</td>
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<tr>
<td>White Poplar</td>
<td>1,694.89</td>
<td>8</td>
</tr>
<tr>
<td>White Walnut</td>
<td>2,242.42</td>
<td>6</td>
</tr>
<tr>
<td>Unidentified</td>
<td>7,358.51</td>
<td>12</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>115,496.46</strong></td>
<td><strong>238</strong></td>
</tr>
</tbody>
</table>
ACKNOWLEDGEMENT

I would like to thank Dr. Christie Klimas for all of her guidance, support, and patience with me throughout this project. I would like to thank Dr. Jim Montgomery, who offered us his extensive knowledge of PWS and often accompanied us to PWS. The Department of Environmental Science and Studies at DePaul University has been relentless in their support of this project, and for that, I would like to thank you. And lastly, I would like to thank my teammates, Michael Berry, Carla Ramirez, Allison Williams, and Ashley Young for all of their help and laughs, in and out of the lab and field.

REFERENCES


